

An Experimental Approach Towards Characterizing the Transient Response of Drain Water Heat Recovery Systems

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Applied Science
in
Mechanical and Mechatronics Engineering

Waterloo, Ontario, Canada, 2019

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Drain Water Heat Recovery (DWHR) systems recover thermal energy from the gray water and use it to pre-heat incoming mains water. So far, the research conducted in this field has focused on the steady-state (SS) operation of DWHR systems. It has now become important to characterize the transient behaviour of DWHR systems, so that it could be included in energy simulation models. The ultimate focus of this thesis was to study the transient response of various DWHR systems, and in particular, to estimate the time it would take to reach quasi-steady-state operating conditions.

The analysis was approached using two experimental methods. The first approach dealt with estimating the time dependent rate of heat recovery, based solely on the fluid inlet and outlet temperatures and flowrates. Correlations were used to estimate 63.2% and 86.5% steady-state time responses. The correlations were validated by performing random experiments. The predicted and experimental time responses were in good agreement. The second approach used infrared thermography to estimate fluid temperatures through the DWHR systems, along with estimating the time responses. This approach provided an estimation of energy storage in the DWHR during transient operation. The time responses derived by both methods were compared.

It was found that both the 63.2% and 86.5% time responses increased with increasing DWHR system length and decreasing flowrate. The time responses estimated using infrared thermography were always a few seconds longer than the first approach.

Recommendations were made to suggest ways to improve and build on the current work. One of the major recommendations was modification of the Heat Exchanger Test Platform (HXTP), to better facilitate transient experiments.

Acknowledgements

First of all, I would like to thank my supervisor, Professor Michael Collins, for providing me with the opportunity to work on this research project. I am really grateful for the technical skills and knowledge that I have learned from him in the last couple of years. It has been a pleasure to be a part of his research team.

I really appreciate the honest feedback provided by Ramin Manouchehri, who always tried to guide me in the right direction with my project. His advanced knowledge about DWHR systems always inspired me to look at my research problem from a more interesting perspective.

I would also like to acknowledge the support of Julian Howarth, with whom I shared the office space. His strong knowledge and hands on skills helped me to set-up my thermography experiments in a better way. He also supported me by peer-reviewing my work.

The support provided by RenewABILITY Energy Inc. is greatly acknowledged. They provided all the DWHR systems that were tested for the experiments conducted in this thesis.

A special thanks goes to Professor Kyle Daun, who trusted me with his thermal camera. It is because of the thermal camera that this research project has been completed successfully.

I am really thankful to my parents Manjinder Singh Dhillon and Rupinderjeet Dhillon, who have always supported me at every step of my life.

Dedications

This thesis is dedicated to my brother “***Jasjeet Singh Dhillon***” who always stood firmly beside me during my high’-s and low’-s.

I can’t wait to see you graduate from Waterloo Mechanical Engineering in the summer of 2020.

You will be a way better Mechanical Engineer than I am.

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List of Abbreviations

ASTM	American Society for Testing and Materials
CSA	Canadian Standards Association
CSV	Comma Separated Value
DAQ	Data Acquisition
DWHR	Drain Water Heat Recovery
FM	Flow Meter
HX	Heat Exchanger
HXTP	Heat Exchanger Test Platform
ID	Internal Diameter
IR	Infrared
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
L/hr	Litres per Hour
LPM	Litres per Minute
OD	Outer Diameter
RTD	Resistance Temperature Device
SS	Steady-State
STRL	Solar Thermal Research Laboratory
UW	University of Waterloo

Nomenclature

A_c	Cross-sectional area (m^2)
Bi_{lam}	Laminar Biot number (Dimensionless)
Bi_{turb}	Turbulent Biot number (Dimensionless)
$c_{p,c}$	Specific heat capacity of cold mains-side water (kJ/kgK)
d_h	Hydraulic diameter (m)
dT/dt	Change in coil set temperature at different time instants (K/s)
D	Coil mean diameter (m)
De	Dean's number (Dimensionless)
h	Convective heat transfer coefficient (W/m^2K)
h_{lam}	Laminar convective heat transfer coefficient (W/m^2K)
h_{turb}	Turbulent convective heat transfer coefficient (W/m^2K)
k_{solid}	Thermal conductivity of copper (W/mK)
k_{water}	Thermal conductivity of water (W/mK)
L	Litres
L_c	Characteristic length (m)
L_{DS}	Drain-side length (inches)
\dot{m}	Mass flowrate (kg/s)
Pr	Prandtl number (Dimensionless)
q_c	Cold mains-side heat transfer rate (kW)
$q_{c,SS}$	Steady-state cold mains-side heat transfer rate (kW)
q_{conv}	Convective heat transfer rate (kW)
q_{flow}	Mains-side flow energy transfer rate (kW)
Q_{flow}	Mains-side flow heat gain (kJ)
$q_{flow,SS}$	Steady-state mains-side flow energy transfer rate (kW)
$q_{flow,63.2\%}$	63.2% of steady-state mains-side flow energy transfer rate (kW)
$q_{flow,86.5\%}$	86.5% of steady-state mains-side flow energy transfer rate (kW)
$q_{storage}$	Storage heat transfer rate (kW)
Re_d	Reynolds number (Dimensionless)
$t_{63.2\%}$	63.2% steady-state time response (s)
$t_{86.5\%}$	86.5% steady-state time response (s)
$t_{99\%}$	99% steady-state time response (s)
$T_{ambient}$	Ambient room temperature ($^{\circ}C$)
T_{ci}	Cold mains-side inlet temperature ($^{\circ}C$)
T_{co}	Cold mains-side outlet temperature ($^{\circ}C$)
T_{hi}	Hot drain-side inlet temperature ($^{\circ}C$)
T_{ho}	Hot drain-side outlet temperature ($^{\circ}C$)
u_c	Instrumental uncertainty (m)
u_d	Design stage uncertainty (m)
u_0	Random error (m)
V	Fluid velocity (m/s)
\dot{V}	Volumetric flowrate (m^3/s)
\dot{V}_{CSA}	CSA flowrate (LPM)
\forall	Coil set internal volume (m^3)

Greek Symbols

ε_c	Steady-state effectiveness of the DWHR system (Dimensionless)
ε	Emissivity of copper (Dimensionless)
α	Absorptivity of copper (Dimensionless)
τ	Transmissivity of copper (Dimensionless)
τ_{flow}	Time constant for flow energy transfer rate (s)
τ_c	Time constant for mains-side heat transfer rate (s)
ρ	Reflectivity of copper (Dimensionless)
ρ_c	Density of mains-side water (kg/m ³)
μ	Dynamic viscosity of water (Ns/m ²)

Chapter 1 Introduction

1.1 Background

Energy consumption and conservation are issues that have been of deep interest in recent years. A lot of research has dealt with the conservation of energy, where the focus is not only to reduce energy usage, but also to recycle some of the energy which would otherwise be wasted. An example would be the extraction of energy in the form of heat from warm drain water to use in the preheating of incoming potable water.

In North America, hot water consumption represents a large share of total building energy usage. In the USA and the European Union, domestic hot water production accounts for approximately 18% and 14% of total energy consumption in the residential sector [1]. Americans on average spent about \$34 billion on residential water heating in the year 2010 [2]. Hence, it is clear that water heating is one of the leading sources of energy consumption.

The idea of preheating incoming potable water with thermal energy from drain water has a lot of potential for re-using energy that would otherwise be wasted. In practical applications, the preheated mains water could be used for any household purposes like showers, dishwashing, etc. A device that is capable of reclaiming energy from the waste drain water is Drain Water Heat Recovery (DWHR) system.

DWHR systems are counter-flow heat exchangers (HX). The majority of commercial products consist of a copper mains pipe that is tightly coiled around the drain stack. A typical DWHR system is shown in Figure 1-1.



Figure 1-1: Typical DWHR system

The larger diameter (drain-side) pipe is where warm gray water flows by forming a falling film on the inside surface of the drain-side pipe. This film rapidly imparts its heat to the pipe wall [3]. This smaller diameter pipe, which is coiled around the drain pipe, represents the cold mains-side of DWHR systems. As the incoming potable water flows through the coils, it extracts heat from the gray water and leaves at a higher temperature. Both of the fluid streams remain unmixed, and there is no possibility of any mains water contamination. Figure 1-2 shows the water flow configuration through a DWHR system.

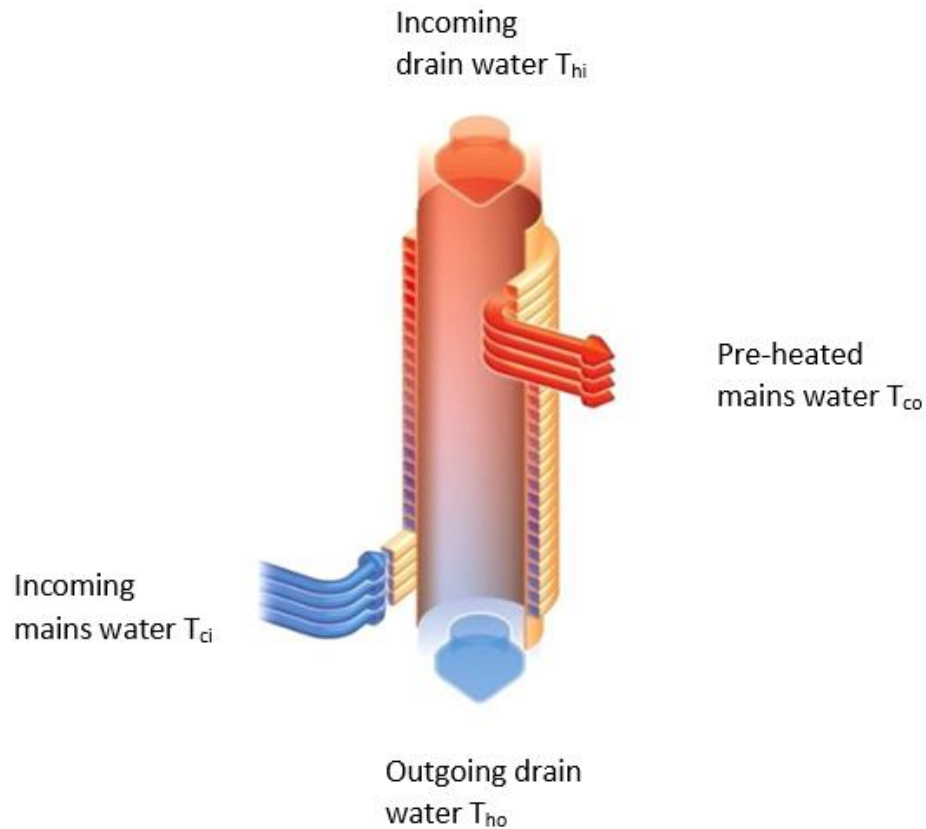


Figure 1-2: DWHR water flow configuration [3]

1.2 Review of Literature related to DWHR Systems

DWHR systems are the centre of attention of this thesis. Hence, the research work related specifically to DWHR systems will be reviewed first. Steady-state aspects of DWHR systems have been investigated in several recent studies conducted at the University of Waterloo (UW) [4] [5] and elsewhere [6] [7]. This section starts with a study to demonstrate the potential DWHR systems have when it comes to energy recovery. The next two studies summarize some of the

other research work conducted on DWHR systems. The last few studies deals with some in-situ studies related to DWHR systems.

1.2.1 Study # 1

Title: Analysis of Profitability of using a Heat Recovery System from Grey Water Discharged from the Shower [8]

The purpose of this study was to demonstrate the benefits of heat recovery, by installing a DWHR system below the shower on a single family dwelling. Two different DWHR system configurations were considered and modelled as shown in Figure 1-3. Method 1 used supplemental heating sources in multiple locations with the DWHR system only preheating shower water. Method 2 used the DWHR system to preheat all water going to the hot water boiler, and more closely resembled the way in which DWHR systems are predominantly installed.

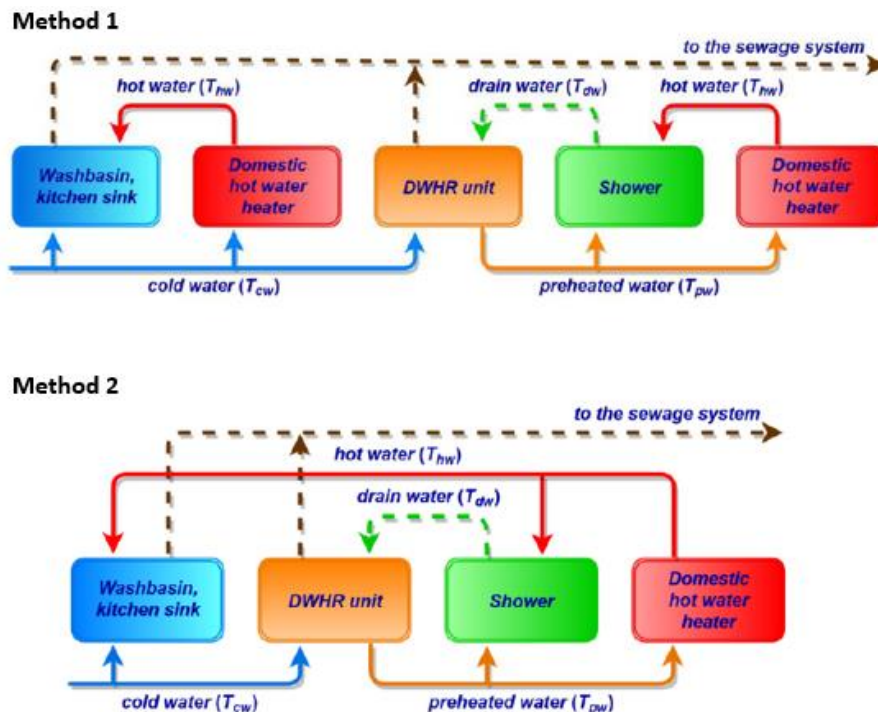


Figure 1-3: Different heating methods with single and double water heaters [8]

The main assumptions made in order to simplify the analysis were equal-flowrates for both fluid streams, and negligible heat loss from the DWHR system. The study was further simplified by assuming that each occupant was using the shower only once per day, and that the water drawing habits did not change for any occupant.

The results indicated that the DWHR systems performed better for Method 1. In that case, at a flowrate of 6 litres per minute (LPM), the heat recovery rate was 7.4kW. With increasing flowrates, the heat recovery rates also increased and the final energy demand was still lower when compared to Method 2. This study provided a good indication about the energy recovery potential of DWHR systems and why more research was required in this field.

1.2.2 Study # 2

Title: Characteristic Effectiveness Curves for Falling-Film Drain Water Heat Recovery Systems [9]

This experimental study, conducted at the University of Waterloo (UW), focused on examining the performance of DWHR systems at various equal-flow conditions. More specifically, the effectiveness of DWHR systems with parallel and counter-flow configurations was examined as a function of volumetric flowrate. The theoretical effectiveness curve of DWHR system performance is shown in Figure 1-4.

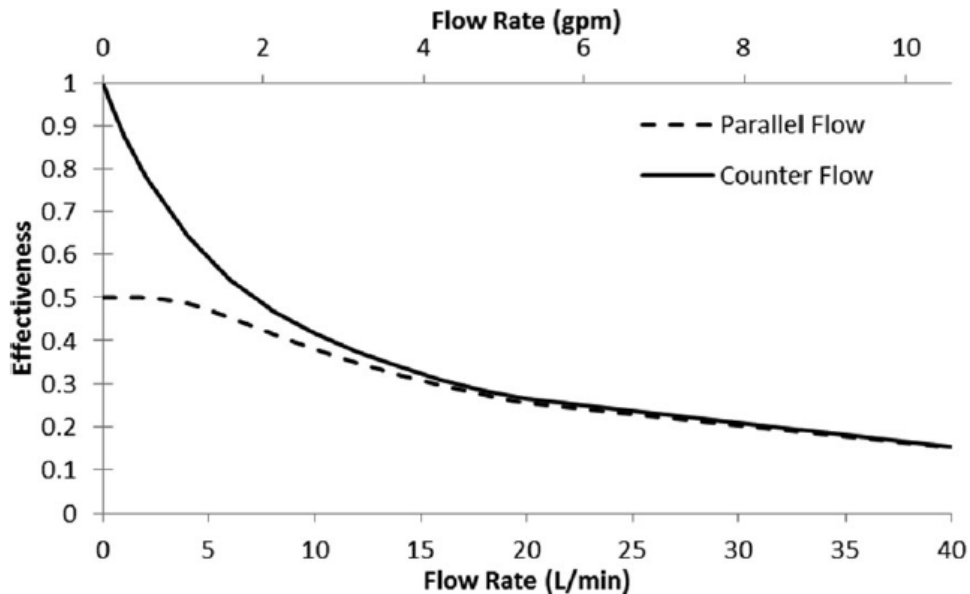


Figure 1-4: Theoretical effectiveness vs volumetric flowrate of a DWHR system [9]

All of the test cases produced curves similar to the one shown in Figure 1-4, with the exception of the inflection point at lower flowrates. The authors concluded that the inflection point was not likely due to transition to turbulence on the mains-side of DWHR systems, since it is predicted to occur at higher flowrates than what the DWHR systems would typically experience. Hence, the inflection point was most likely due to the transition to turbulence on the

drain-side. More research and investigations on DWHR system behaviour were recommended. This study provided a very brief insight about the nature of fluid flow inside the DWHR system.

1.2.3 Study # 3

Thesis Title: Predicting Steady-State Performance of Falling-Film Drain Water Heat Recovery Systems from Rating Data [10]

This experimental investigation on DWHR systems, followed from study # 2, and focused on characterizing the performance of DWHR systems under steady-state conditions. The work focused on the performance of DWHR systems under varying inlet temperatures, and equal and unequal-flow conditions. Semi-empirical models were developed, and used to compare the predicted and measured heat transfer rates and effectiveness. It was concluded that the percent difference between the measured and predicted heat transfer rates was within 4%. The flowrates investigated ranged from 5.5 to 14LPM. Correction factors were also developed to allow for extrapolation of the results for this model to higher flowrates. The author also showed that the inflection point mentioned in the previous study was due to break-down of the drain-side film.

Figure 1-5 shows the Heat Exchanger Test Platform (HXTP) that was constructed in Solar Thermal Research Lab (STRL) at UW for studying DWHR systems.

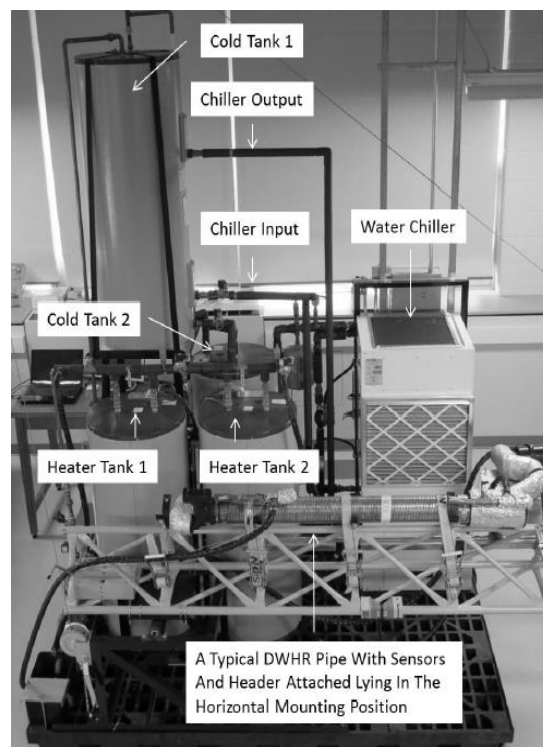


Figure 1-5: HXTP set-up in STRL [10]

The model that was developed did not take transient effects into account. The study of transient behaviour of DWHR systems was stressed in the recommendations and is the motivation for the current studies being performed.

1.2.4 Study # 4

Title: In-Situ studies related to DWHR systems [11] [12] [13] [14] [15]

Several studies looked at the in-situ energy performance of DWHR systems [11] [12] [13] [14] [15]. These works are not directly related to the current research, but will be briefly discussed.

The first study was performed by Zaloum et al. [11], at the Canadian Centre of Housing Technology, with the scope of determining the heat recovery benefits of DWHR systems, using standard operating conditions. Five different DWHR systems from 3 different manufacturers were installed in a basement and tested under different flow configurations. It was concluded that DWHR systems reduced natural gas consumption for water heating by 9 to 27%

The next study was performed by Bartkowiak et al. [12] in Ann Arbor Michigan, in order to investigate the energy improvements that can be achieved by using DWHR systems. Cold water was supplied by the residential water main at approximately 7 °C. At the same time, hot water was generated using a 300 litres natural gas hot water tank maintained at 49°C. Monte-Carlo simulations were performed to characterize the variation in annual savings of a typical US household. It was concluded that over a range of tested showering conditions, the energy savings ranged from \$74 to \$160/year, depending on the type of water heating.

A third study was performed by Tanha et al. [13] in Vaughan Ontario, to understand the performance of DWHR systems along with two solar domestic water heaters. The DWHR systems were installed in identical houses, labelled as house A and house B. Identical DWHR systems were installed in both the houses, with the difference of the solar collectors and types of water heaters. It was concluded that DWHR systems were capable of an annual heat recovery of 789 kWh.

Another study conducted by Wong et al. [14] in Hong Kong investigated the potential of heat recovery from shower water from bathrooms equipped with instantaneous water heaters. For this study, a simple single-pass counter-flow heat exchanger was installed beneath the shower drain. Shower usage patterns and durations were sampled from an interview survey

conducted on 1300 households of 14 typical high-rise buildings. The results indicated that 4-15% of shower water heat could be recovered through a 1.5m long single-pass counter-flow heat exchanger for the drainage pipe of 50mm.

The last study conducted by Oak Ridge National Laboratory [15] focused on evaluating the performance of a 60" long DWHR system in the basement of a single family home in Knoxville, Tennessee. The set-up allowed the authors to investigate the performance of DWHR system at both equal and unequal flow conditions. The results showed that the DWHR system was able to induce energy savings between 30-50%.

The main purpose of presenting the in-situ studies was to demonstrate the energy and cost saving potential of DWHR systems.

1.3 Review of Literature related to Transient Response of Heat Exchangers

All of the studies examined in Section 1.2 either dealt with the steady-state aspects of DWHR systems, or with overall system performance. Unfortunately, almost no research exists about the transient operation of DWHR systems. The transient behaviour, is important when the system undergoes time-varying input conditions, which may result from external load variations such as a shower start-up, a tap opening or flushing of a toilet etc. In all those cases, the system will be acting in transient. Currently, this cannot be captured by modelling. So, for example, if a hot water tap is turned on, models will show instantaneous energy recovery even for that case. In reality, the hot water may never have reached the taps, and no energy may have been exchanged. Load fluctuations can cause disturbances in inlet fluid temperatures and flowrates [16] which must be accounted for in the energy models.

In case of DWHR systems, transient aspects becomes important when the system is run after a long period of time, and the water in the mains coils have reached ambient conditions. Investigating the transient response of DWHR systems is also important so that these effects can be implemented in building simulation models.

Several works were reviewed that considered transient response of heat exchangers in general. This section summarizes those works.

1.3.1 Study # 5

Title: Analytic Model for Transient Heat Exchanger Response [17]

This study conducted at the Rensselaer Polytechnic Institute, aimed to investigate the transient behaviour of HX, in which one fluid was single phase and the other had a constant temperature, using an analytical approach. Two different cases were considered: (1) when the constant temperature fluid undergoes a step change in temperature, and (2) when a single phase fluid undergoes a flowrate step change. The analysis provided the time varying fluid and tube wall temperatures over the whole length of the HX. For both cases, explicit analytical solutions were developed and validated by comparison against the numerical solution results over a wide range of operating conditions. Figure 1-6 shows one case of the validation of an analytical model. Both the numerical and analytical models were in good agreement.

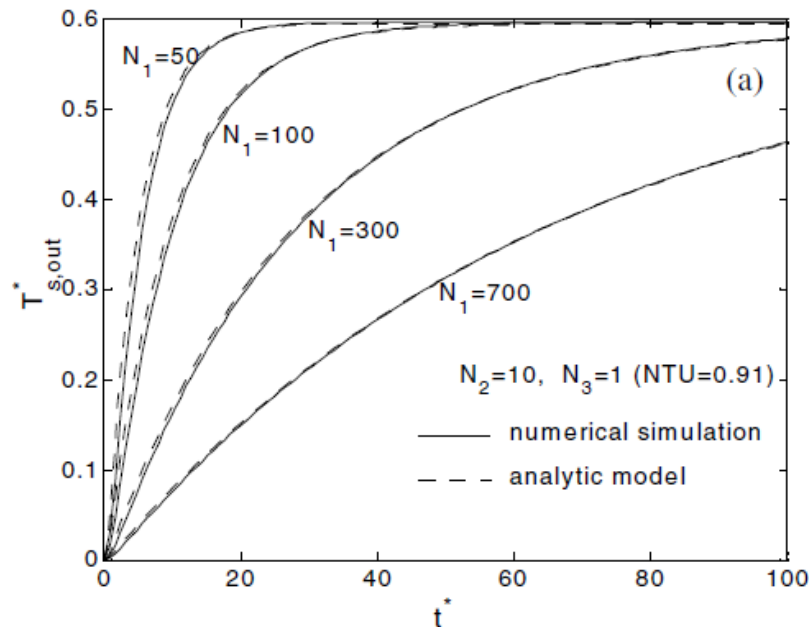


Figure 1-6: Sample validation of analytical model with numerical results [17]

Step change input conditions for temperature and flowrates were used with one of the fluid temperatures kept constant. This is not the case for an ideal transient HX response, where all the inlet and outlet temperatures change until they settle at some final steady-state conditions. No experimental validation was performed on the model itself. The work provided some insight on the expected shape of the transient temperature versus time behaviour of HXs.

1.3.2 Study # 6

Title: Cross Flow Heat Exchanger Modeling of Transient Temperature Input Conditions [18]

This cross flow HX modelling conducted by Gao et al., focused on predicting the cross flow HX dynamics under arbitrary input temperature conditions. Step, ramp and exponential inlet boundary conditions were studied, and the outlet temperature response times were evaluated.

The model presented relied on the numerical solution of the model equations. The numerical solution provided performance relationships, whereas a polynomial regression helped to determine simplified relationships for predicting response time of the HX. It was found that different initial input conditions (idle or steady-state) of the HX did not affect the transient response time.

Second order polynomial equations were developed to estimate the time responses for different type of input conditions. The model used air as one of the working fluids for a cross flow HX, since the focus of this study was to predict the transient behaviour of HX used in data center cooling equipment. It was found that the initial and final values of inlet temperature variation function did not influence the transient behaviour of the fluid outlet temperature. This study provided an understanding about using time constants as a metric for transient response of the HX outlet temperature.

1.3.3 Study # 7

Title: Transient Analysis in Heat Exchangers [16]

A survey of new developments on the transient analysis of HX was presented in this heat exchanger textbook. Applications of a transient HX model were introduced. Based on the model, general mathematical descriptions of the dynamic response of HX were provided, and the effect of the dispersion coefficient on the transient behaviour was analyzed. The authors provided a brief review of the previous work done in the field. They concluded that previous models assumed plug flow, which meant that the flow in the HX was uniform everywhere. The actual flow, however, is very complicated and various forms of flow mal-distributions occur. This deviation from the ideal plug flow pattern has great influence on the dynamic response of HX. The authors concluded that an axial dispersion model is most suitable for dynamic simulations of processes.

For the axial dispersion model, emphasis was placed only on the mathematical models. Analytical solutions for transient response of heat exchangers were developed using Laplace transforms, Fast Fourier transforms and partial differential methods. The Peclet number (Pe), which is the ratio of heat transfer by fluid motion to the heat transfer by thermal conduction was used to describe the effects of mal-distribution on transient behaviour.

For an ideal plug flow, $Pe = \infty$. The final part of the transient chapter in this HX textbook demonstrated an example of using this model. In the example, initially a uniform temperature distribution throughout the HX was achieved, before it was subjected to a sudden change in inlet shell side temperature. The quantitative description revealed that the effect of mal-distribution was stronger if $Pe < 25$. For $Pe > 55$, the dispersion model was identical to the plug flow model.

1.3.4 Study # 8

Title: Experimental Study on Transient Behaviour of Embedded Spiral Coil HX [19]

This experimental study, conducted at Prince Mohammad Bin Fahd University, focused on the transient flow behaviour in spiral shaped circular cross-sectional tubes where the coil was embedded in a rectangular conducting slab. Results were shown for the derived heat transfer based on factors like tube diameter, coil curvature, coil orientation, coil pitch, shell and tube side flow, number of loops and Reynolds number. Once the test started, the data was collected for 2 hours so that the whole process could reach steady-state. In this study, a dimensionless temperature, which was a combination of coil and fluid inlet and outlet temperatures, was plotted against time. Figure 1-7 shows the impact that the number of loops had while approaching steady-state.

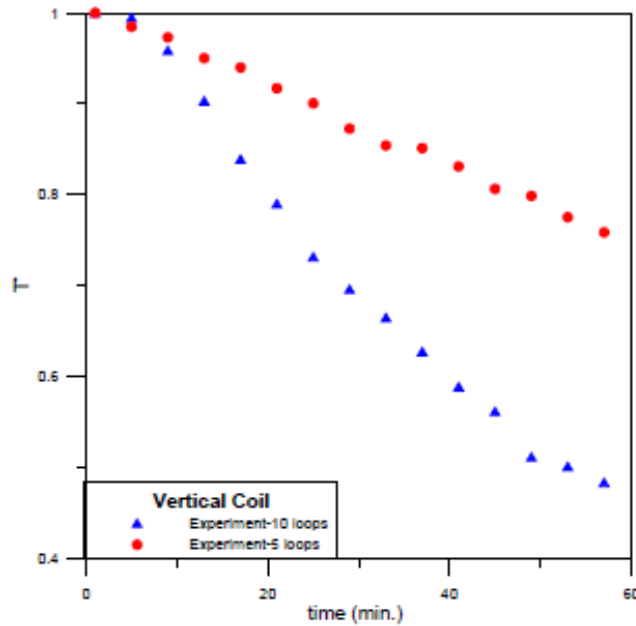


Figure 1-7: Impact of number of coils on reaching steady-state [19]

The comparison of the normalized temperature shows that increasing the number of loops would increase the rate of heat transfer despite the identical length of 2 different coils. The author briefly discussed the theory behind the heat transfer coefficient in helical coils, thereby providing insight on the application of heat transfer coefficients on helical coils.

1.4 Review of Literature related to Infrared Thermography of Heat Exchangers

Both the steady-state and transient studies in Section 1.2 and 1.3 mostly focused on the fluid temperatures at the inlet and outlet of the DWHR systems or HXs. The investigation of mains-side water temperature throughout the DWHR system length could help in examining the transient response more accurately.

One way to estimate the fluid temperatures across the entire HX is with the help of thermal imaging. Hence, studies related to the use of infrared thermography on HX were reviewed. Only a limited number of studies were found, and were reviewed to understand the methodology that has been used.

1.4.1 Study # 9

Title: Investigations of a Heat Exchanger using Infrared Thermography and Artificial Neural Networks [20]

In this experimental study, an investigation of a heat exchanger was performed at steady-state, using infrared thermography. More specifically, a single panel radiator was used. The main purpose of this research paper was to propose a new algorithm for the inverse heat transfer problem of calculating the power consumption of the heat exchanger being investigated. The algorithm developed was based on a supervised artificial neural network, which was trained using the data obtained from the infrared thermography measurements. The temperature fields or thermograms were obtained for the frontal surface of the radiator under investigation. Figure 1-8 shows the schematic of the algorithm used to calculate heat power consumption using neural networks, where f^1 and f^2 were the transfer functions for the neurons in the hidden and output layer respectively.

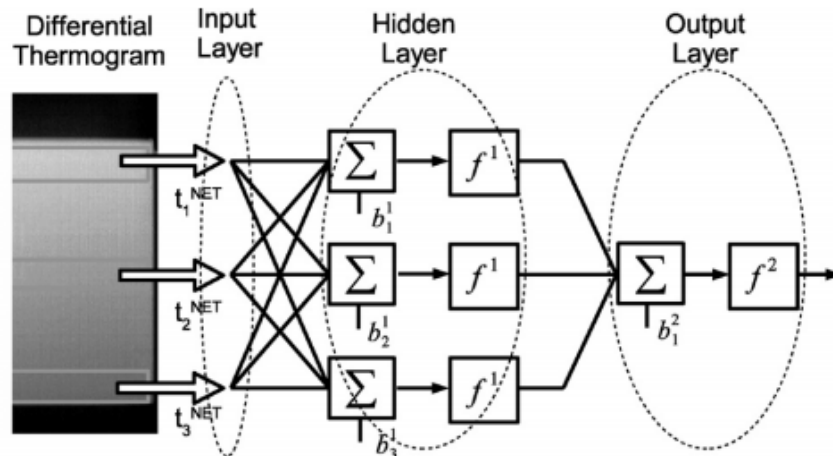


Figure 1-8: Schematic of algorithm used for heat power consumption calculation [20]

The heat power consumption was measured using 2 methods. In the first method, a standard HX operating curve determined in a closed chamber, based on the European EN 442-2 [21] standard was used. The second method was based on the difference between the inlet and outlet enthalpy of the supplied water. The thermograms for the frontal surface temperature measurements of the radiator were recorded with the frame rate of 1 frame per second, and were used in the development of the algorithm.

It was concluded that by using the neural network, the steady-state power consumption could be estimated with a limiting error of about 2%. In this study, the major focus was on the

development and performance of the neural networks. No information was derived about the fluid properties inside the HX. This study provided insight into how infrared thermography could be used to study DWHR systems.

1.4.2 Study # 10

Title: Local Heat Transfer Measurements of Plate Finned-Tube Heat Exchangers by Infrared Thermography [22]

The focus of this experimental study was to monitor the temperature distribution over a plate-fin surface inside the plate finned-tube heat exchangers. The local convective heat transfer coefficients over the fin were determined by a control volume based finite difference formulation, after the temperature values were established on the surface of the plate-finned heat exchanger.

The experimental set-up consisted of a wind tunnel, in which the tubes were installed either in staggered or in-line configurations. Eight type K thermocouples were mounted evenly on the inlet and outlet section of the test model. The thermal camera used, had the ability to capture thermograms up to the rate of 60 frames per second.

Thermographic measurements for the frontal surface temperature of the tubes were taken once the air flow had reached steady-state conditions in the air duct. After the frontal thermograms were recorded, a control volume based energy balance was applied to the sections of interest. Figure 1-9 shows the energy balance schematic for the estimation of convective heat transfer coefficients.

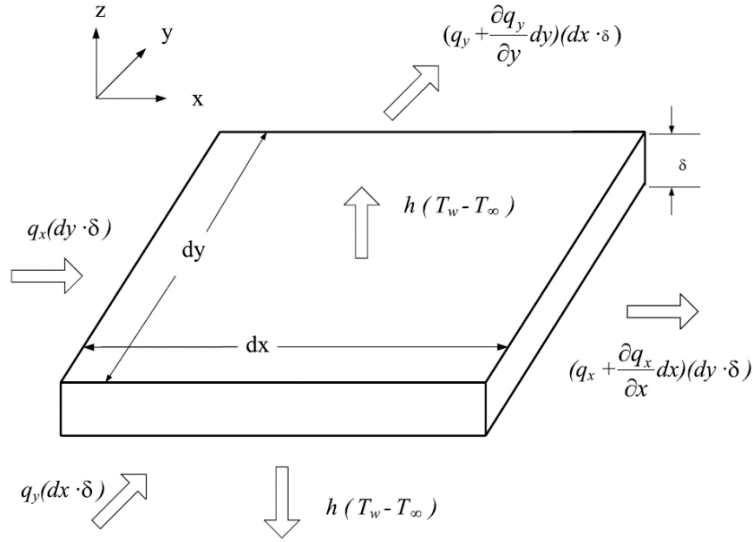


Figure 1-9: Energy balance applied to estimate convective heat transfer coefficient [22]

It was determined that if the Reynolds number was lower than 2172 for the in-line array of heat exchangers, the span-averaged convective coefficient profile on the fin would be similar to that of pipe flow. For Reynolds number greater than 3258, a lot of roughness was observed in the local convective coefficient curves. It was also demonstrated that the averaged heat transfer coefficients of a staggered configuration was 14-32% higher than that of the in-lined configuration. This study was conducted under steady-state conditions using air as the working fluid. This study showed a possible application of thermocouples, thermal camera and energy balance while performing experimental analysis on any kind of heat exchangers.

1.5 Research Question

The review of the literature has shown that experimental studies of DWHR systems have focused solely on steady-state behaviour. Further, studies of transient HX behaviour have been done, but not on the conditions experienced in DWHR systems, and only on an analytical basis. The current work aims to bridge this gap.

The overall objective of this thesis is to experimentally investigate different transient aspects of DWHR systems. To do this work, two experimental approaches will be employed. The first approach will rely only on the flowrate along with inlet and outlet temperatures of DWHR systems. The second approach will include the use of infrared thermography on DWHR systems.

For both test methods, inlet and outlet temperature profile development, nature of heat recovery curve, and the time responses of DWHR systems will be investigated. At the end, time responses derived from both experimental approaches will be compared.

The nature of mains-side water temperature change across the entire length of DWHR system, along with the temperature change across different sections of DWHR systems will be investigated using the infrared thermography approach.

1.6 Thesis Breakdown

The topics covered and chapter descriptions in this thesis are as follows:

- **Chapter 2** – Is an introduction to energy balance and heat transfer rates, and a description of test method 1 and the HXTP. An estimation of equipment uncertainty is also included.
- **Chapter 3** – Included the data analysis, results and discussions related to test method 1. Repeatability of the experimental measurements is established. An estimation of flow energy transfer rates (q_{flow}) and time responses is made.
- **Chapter 4** – Is an introduction to infrared thermography and test method 2. Equipment preparation and set-up related to test method 2 is described.
- **Chapter 5** – Is the data analysis, results and discussions related to test method 2. A study of temperature profiles throughout the DWHR system is performed, and estimation of system energy storage (q_{storage}), mains-side heat transfer rates (q_c) and time responses is performed.
- **Chapter 6** – Contains the conclusions and recommendations resulting from this work.
- **Appendix A to C** – Contains plots and tables associated with test method 1.
- **Appendix D to P** – Contains plots and tables associated with test method 2.

Chapter 2 Test Method 1

2.1 Introduction to DWHR Heat Transfer Rate

Assuming no energy generation, the overall energy rate balance applied over the entire DWHR system could be written as:

$$E_{in} - E_{out} + Q_{in} = E_{stored} \quad (2.1)$$

The 3 components in Equation 2.1 are heat transfer rate by inlet and outlet flow of mains-side water, mains-side heat transfer rate and storage effects.

Figure 2-1 shows the schematic of the overall energy balance applied to the entire DWHR system.

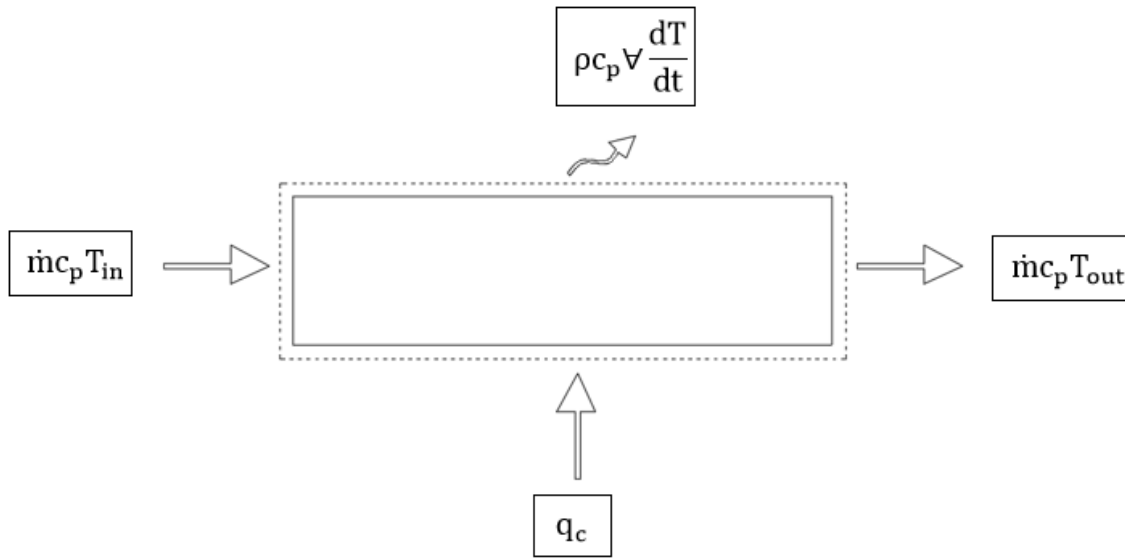


Figure 2-1: Schematic of energy balance on DWHR system

Substituting the energy balance variables from Figure 2-1 into Equation 2.1 yields Equation 2.2.

$$\dot{m}c_p T_{in} - \dot{m}c_p T_{out} + q_c = \rho c_p V \frac{dT}{dt} \quad (2.2)$$

Further simplification of Equation 2.2 leads to the derivation of the cold mains-side heat transfer rate (q_c), which is the same as heat recovered from the wastewater and is shown in Equation 2.3.

$$q_c = \dot{m}c_p(T_{out} - T_{in}) + \rho c_p V \frac{dT}{dt} \quad (2.3)$$

Equation 2.3 could be further broken down into two different components shown in Equation 2.4 and Equation 2.5.

$$q_{flow} = \dot{m}c_p(T_{out} - T_{in}) \quad (2.4)$$

$$q_{\text{storage}} = \rho c_p V \frac{dT}{dt} \quad (2.5)$$

In Equation 2.4, q_{flow} is the mains-side flow energy transfer rate in kW, \dot{m} represents the mass flowrate of mains-side water in kg/s, c_p is the specific heat capacity of mains-side water in kJ/kgK and $(T_{\text{out}} - T_{\text{in}})$ is the difference between mains-side outlet (T_{co}) and inlet water temperature (T_{ci}) in K.

Similarly in Equation 2.5, q_{storage} is the energy storage rate in kW. ρ , V and $\frac{dT}{dt}$ represent the density of mains-side water in kg/m³, volume of water in DWHR coils in m³ and the change in mains-water temperature for the entire DWHR system throughout the duration of the test in K/s. Storage effects play a crucial role during the beginning phases of a test due to the changing dT/dt term.

Unfortunately, the previous test approaches were for steady-state analysis, and didn't account for energy storage effects in the DWHR systems. As such, they relied only on mains-water inlet and outlet temperatures. The work described here consisted of two experimental approaches. Both approaches relied on an existing DWHR experimental test platform located in the STRL at UW. For the first test method, time responses will be calculated using the current generalized approach, solely based on q_{flow} . In the second approach, due to the introduction of infrared thermography, time responses will be calculated, but q_c and q_{storage} will be estimated.

2.2 HXTP Set-Up and Experimental Procedures

2.2.1 HXTP Set-Up

The HXTP was constructed by the STRL at UW for the purpose of performing research on DWHR systems. A secondary goal of the test platform was to perform steady-state testing and Canadian Standards Association (CSA) certification of the DWHR systems [10]. CSA develops standards in testing, inspection and certification for a broad array of industries. Figure 1-5 and Figure 2-2 show a photo and schematic of the HXTP used for the current experiments. A detailed description of the HXTP is provided in the MASc thesis of Manouchehri [10]. A brief overview of how the HXTP operates, and the modifications made to accommodate the current research, are described here. The greyed flow paths in Figure 2-2 were used in other studies or during system set-up, and are not relevant to the present study.

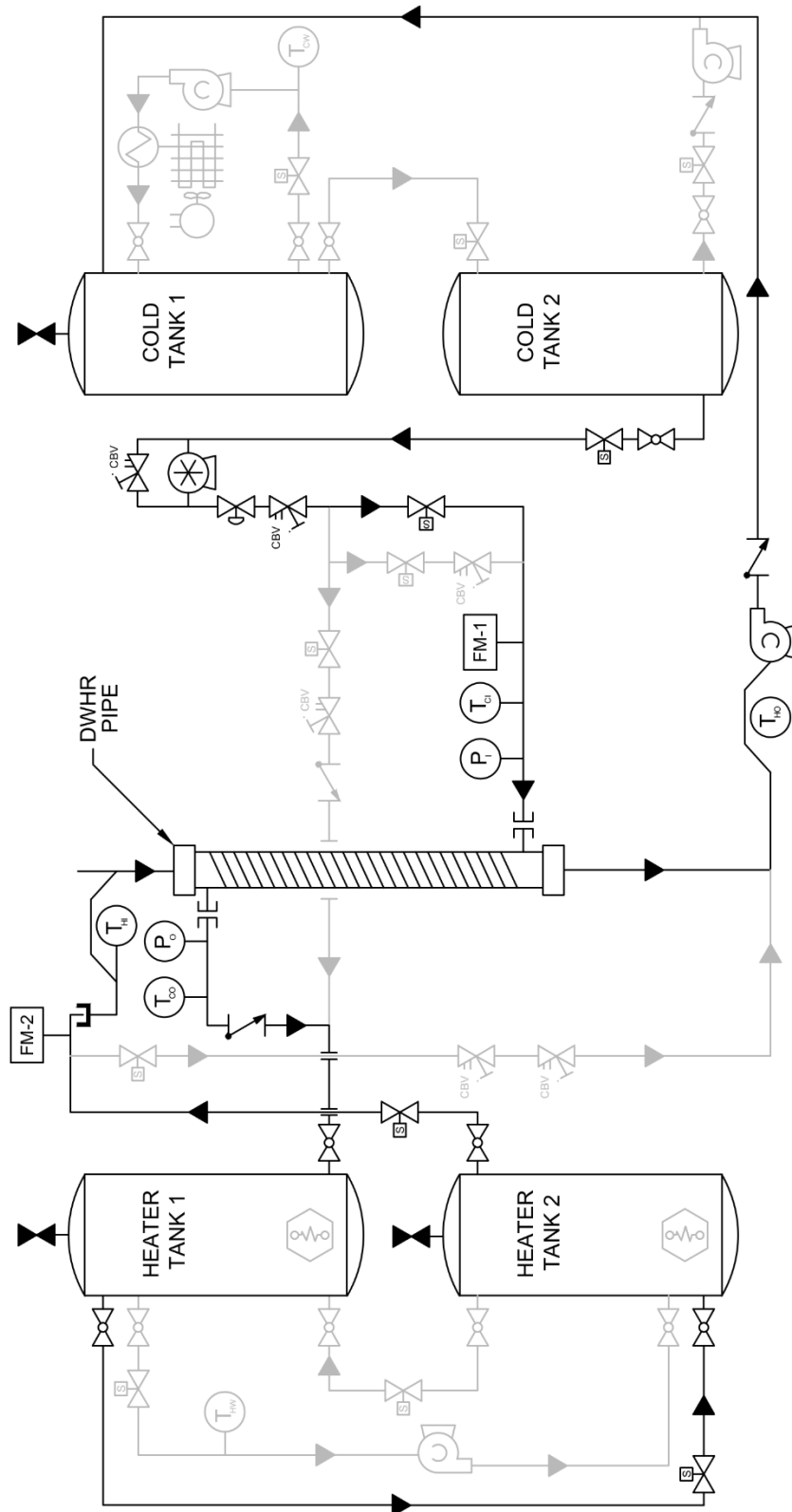


Figure 2-2: Schematic of HXTP [10]

	ONE WAY VALVE		AIR PRESSURE RELEASE VALVE		WATER TO AIR HEAT EXCHANGER SINGLE PASS		CENTRIFUGAL PUMP		FLOW DIRECTION		FLOW METER
	BALL VALVE		CIRCUIT BALANCING VALVE		SHOWER SIMULATOR		POSITIVE DISPLACEMENT VANE PUMP		PRESSURE TRANSDUCER		PRESSURE TRANSDUCER
	SOLENOID VALVE		PRESSURE RELIEF VALVE		INSULATED TANK		CENTRIFUGAL PUMP		RTD		RTD

2.2.2 HXTP Operational Overview

With reference to Figure 2-2, the HXTP operated as follows. To determine DWHR operation, constant inlet temperatures are required. The HXTP provides this constant temperature by pre-conditioning a large volume of cold and hot water prior to conducting a test. In this regard, *Cold Tank 1* was conditioned to the desired mains-side inlet water temperature (T_{ci}), while *Heater Tanks 1* and *2* were conditioned to the desired drain-side inlet water temperature (T_{hi}). All tanks were capable of providing a well-mixed and stable water source to within $\pm 0.2^{\circ}\text{C}$ of the desired set point for the duration of a test. The water from *Cold Tank 1* was transferred to *Cold Tank 2* before the start of the test to ensure that the tank was well mixed, and to make sure that *Cold Tank 1* was empty as it was used as a reservoir for water that had been used during the test process.

Once the tanks were conditioned, the DWHR test began. In reference to Figure 2-2, the flow followed a single path through the system. Starting at *Cold Tank 2*, a pump moved the mains-side water to the mains-inlet of the DWHR system. A bypass near the pump, allowed for control of the system flowrate. This water passed through the mains-side coils of the DWHR system, collecting heat from the drain-side, and then made its way to the bottom of *Heater Tank 1* pre-heated to T_{co} .

This water pushed hot water out of the top of the *Heater Tank 2* at the same flowrate. It is important to note that the Heater Tanks were designed such that mixing of the hot and cold water streams occurred very slowly, and had little impact on *Heater Tank 2*'s outlet temperature. Water from the *Heater Tank 2* was then sent to the drain-side of the DWHR system. It formed an annular film around the inner surface area of the drain-side and dissipated its heat to the mains-side water. The water leaving the drain-side of the DWHR system was pumped into *Cold Tank 1* at T_{ho} .

2.2.3 HXTP Data Collection

Instrumentation was installed at various locations in the system (Figure 2-2). A flowmeter (FM-1) located after the pump allowed for the measurement of flowrate. Resistance Temperature Devices (RTDs) were situated at the inlets (T_{ci} and T_{hi}) and outlets (T_{co} and T_{ho}) of the DWHR system in immersion wells designed to provide well mixed fluid at the site of

temperature measurement. They were used for measuring the mains and drain-side inlet and outlet water temperatures. Finally, pressure transducers were located on the mains-side inlet (P_{ci}) and outlet (P_{co}) to determine the pressure drop across the system. These pressure transducers are a requirement of the CSA testing process, and were not used in the current work.

2.2.4 HXTP Measurement Equipment Uncertainty

For this research, the main measurement equipment were the flowmeter and the RTDs. The flowmeter could measure flowrates with an overall accuracy of $\pm 1\%$ of the reading [23]. Uncertainty in RTD measurements was calculated as shown by Equation 2.6 [24]:

$$u_d = \pm \sqrt{u_0^2 + u_c^2} \quad (95\%) \quad (2.6)$$

Where u_c was instrument uncertainty and u_0 was the random error from instrument reading. Based on the specification sheets provided with the instruments, u_0 and u_c were estimated to be $\pm 0.1^\circ\text{C}$ and $\pm 0.016^\circ\text{C}$ respectively [25]. The uncertainty of the RTD measurements was estimated to be $\pm 0.1003^\circ\text{C}$.

Error bars are only shown for some temperature plots in this thesis. The main purpose is to demonstrate the measurement error that inherit in temperature readings. Both the flowmeter and RTD uncertainty is applicable to all the experiments performed in this thesis.

2.3 DWHR System Test Conditions

2.3.1 General Requirements

The tests for this work were performed at the specified CSA flowrates and inlet temperatures [26]. For all the experiments described here, the mains and drain-side inlet water temperatures were set to 10°C and 38°C respectively, to mimic water temperatures typically specified during CSA ratings [26].

All of the DWHR systems used in this study have been CSA certified and extensively studied under steady-state conditions, and therefore, there has been a significant amount of data collected about their steady-state performance. The test flow and temperature conditions for the current work are somewhat arbitrary, so it was decided to match test conditions to this existing data.

Table 2-1 shows the summary of CSA flowrates [26] along with mains and drain-side inlet temperatures. All experiments are conducted at equal-flow conditions (i.e. the mains and drain-side flowrates are the same).

Table 2-1: CSA flowrates and inlet conditions

CSA Flowrates (LPM)						T_{ci} ($^{\circ}\text{C}$)	T_{hi} ($^{\circ}\text{C}$)
14	12	10	9	7	5.5	10	38

There is no evidence that ambient conditions have any impact on DWHR performance. Still, efforts were made to keep the ambient room temperature at $22 \pm 2^{\circ}\text{C}$ in order to establish a common starting temperature point for all the experiments.

2.3.2 LabVIEW Interface and Data Acquisition

A LabVIEW interface was built based on the schematic shown in Figure 2-2. The temperature RTDs and the flowmeter were connected to a LabVIEW DAQ, which acquired data such as flowrate, inlet and outlet temperatures after one second intervals for both the drain and mains-side. The LabVIEW interface is shown in Figure 2-3.

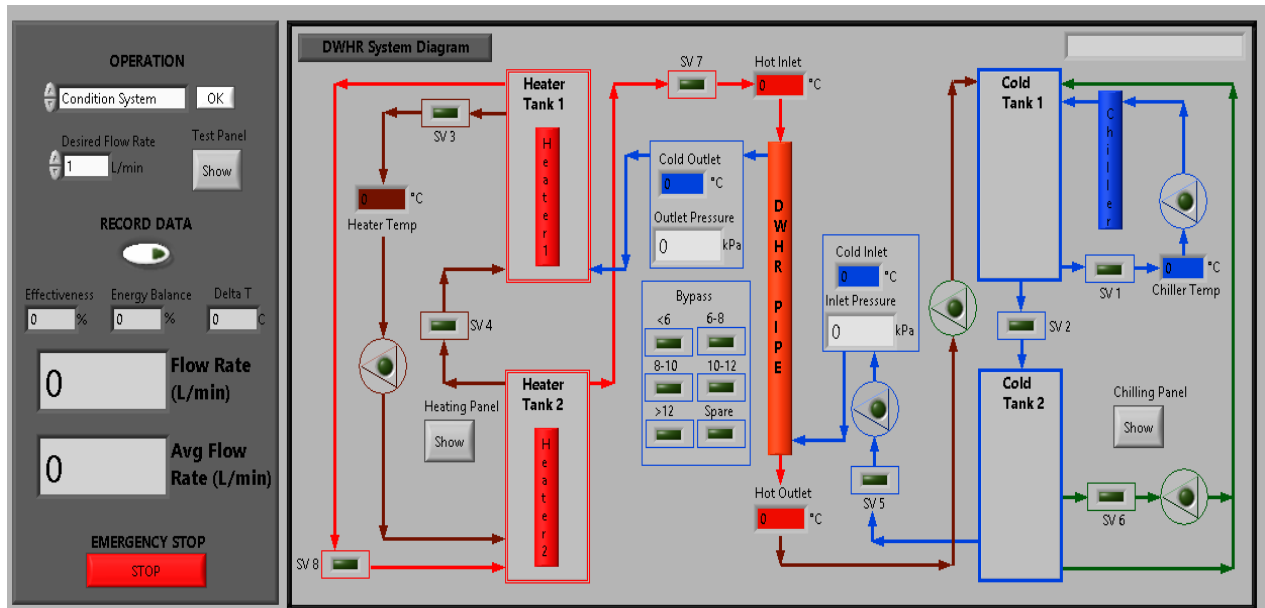


Figure 2-3: The LabVIEW interface used to collect the data

Once the test started and the HXTP operated according to Section 2.2.2, the RTDs, flowmeter and pressure transducers measured the inlet and outlet water temperatures, flowrates and inlet and outlet pressures, respectively. All of the measurements were sampled once per second. Data measurements were acquired once the “Record Data” button was

pressed. The raw data was then stored as an excel file and analyzed as required. The button could be pressed again to stop data acquisition. Once a test was complete, HXTP operation was terminated by pressing the “Stop” button. At that point the water pump along with all measuring devices would stop.

2.4 Data Analysis of Steady-State DWHR Operation

To determine the steady-state performance of a DWHR system, the system operated exactly as described in Section 2.2.2 and 2.3.2. After the DWHR system was installed on the HXTP and the test was initiated, mains and drain-side water flowed, until the temperature readings stabilized around 10°C and 38°C respectively, with no trending in the recorded data. At that point, data was acquired in the form of temperature, pressure and flowrate measurements, which were recorded in the excel file.

Effectiveness is the ratio of heat transfer to the mains-side water, and the maximum heat transfer that could occur in the DWHR system. For steady-state tests, it is calculated for equal mass flowrate and equal fluid specific heats using Equation 2.7 [27].

$$\varepsilon_c = \left(\frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} \right) \times 100\% \quad (2.7)$$

A random sample of collected raw data is shown in Table 2-2, where effectiveness is the only calculated value. The water flowrate was measured in LPM. All of the raw data acquired and the temperature profiles generated for this thesis are available from the STRL at UW.

Table 2-2: Sample of raw data collection with calculated effectiveness

Time (s)	T _{ci} (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	P _{in} (kPa)	P _{out} (kPa)	LPM	ε _c
10	20.22	19.83	20.11	19.79	72.86	42.72	11.80	354.55
11	20.14	19.84	20.18	19.80	74.85	42.33	13.57	-750.00
12	20.01	19.86	20.23	19.83	73.62	41.88	13.70	-68.18
13	18.58	19.98	20.74	19.95	73.41	43.11	13.86	64.81
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
163	9.78	20.97	38.27	26.91	74.74	40.58	13.86	39.28
164	9.78	20.97	38.27	26.90	74.95	40.84	13.83	39.28
165	9.78	20.97	38.27	26.90	74.87	41.21	13.81	39.28
166	9.78	20.97	38.27	26.90	75.31	42.02	13.77	39.28
167	9.78	20.97	38.27	26.92	71.95	40.16	13.77	39.28

2.5 Analysis of Transient DWHR System Performance

2.5.1 Collection of Transient Data using the HXTP

The transient operation of the HXTP was similar to its steady-state operation. The main differences being the initiation of data acquisition. Since transient effects of DWHR systems occurred during the beginning phases of a test, data acquisition had to be initiated at the same instant when the test started. Hence, for all of the transient experiments conducted in this thesis, the “Record Data” button was pressed at the same time when the test was initiated. Data was collected for a long enough time period to include pre-test conditions, through to start-up, and transient and steady-state operation. For all the tests, this meant that data was acquired for roughly 4-5 minutes. The HXTP would remain inactive for the next 5-6 hours to ensure that it had returned to ambient conditions.

During steady-state testing, the flowrate could be adjusted to achieve a desired flowrate. Once the flowrate and inlet temperatures reached steady-state conditions, data could be collected at the desired conditions. Unfortunately, data acquisition during transient analysis was more challenging. To assist in reaching the desired test flowrates, the flowrates for a test were set immediately after the previous test, and before the HXTP was shut down. While this did provide a good test starting point, it was not always perfect due to changes in the HXTP.

2.5.2 Unresponsive Time Periods

After a test started, it was expected that conditioned water would not instantaneously reach the inlets of DWHR system. There would be a short unresponsive period of time in which the conditioned flow made its way through the HXTP to the DWHR inlets. It was after this time period that the inlet RTDs would start to respond to temperature change.

To determine the unresponsive portion of the inlet water temperatures, time periods to reach the mains-side inlet from the HXTP water pump was estimated for each flowrate. The hose length between the pump and mains-side water inlet was measured to be 6.235m. The hose had an ID of 0.75” or 0.01905m. The unresponsive time period was therefore calculated by converting the CSA flowrate into a volumetric flowrate, and dividing it by the volume of the hose.

The unresponsive time periods of temperature profile are summarized for all CSA flowrates in Table 2-3. It is important to note that a decrease in flowrate resulted in longer unresponsive time periods, since the water would take longer to reach DWHR system inlets.

Table 2-3: Estimated time intervals of unresponsive temperature profiles at different flowrates

Flowrate (LPM)	Unresponsive time period (s)
14	8
12	9
10	11
9	13
7	16
5.5	21

The unresponsive time periods were between 8-21 seconds depending on the flowrate. Once the conditioned flow reached this point, adjustments could not be made without influencing the collected data.

2.5.3 Transient Data Analysis

The underlying assumptions surrounding the derivation of Equation 2.7 assumes steady-state operation. For this reason, effectiveness was not used for the purpose of determining the transient responses. Instead, analysis of transient performance will be based on the recorded temperature and q_{flow} histories from each test.

2.5.4 Experimental Uncertainty in Heat Transfer Rates

The uncertainty in transient measurements was determined. To do so, Equation 2.4 was first expanded to Equation 2.8 as follows:

$$q_{\text{flow}} = \rho_c c_{p,c} \dot{V} (T_{\text{co}} - T_{\text{ci}}) \quad (2.8)$$

Where \dot{V} represented the volumetric flowrate in m^3/s which was derived from the measured CSA flowrate.

The uncertainty in the estimated mains-side flow energy transfer rate (q_{flow}) was calculated using Moffat's method [24]. Based on Equation 2.8, the uncertainty was calculated as:

$$\frac{\delta q}{q} = \pm \sqrt{\left(\frac{\delta \Delta T_{\text{cold}}}{\Delta T_{\text{cold}}}\right)^2 + \left(\frac{\delta \dot{V}_{\text{cold}}}{\dot{V}_{\text{cold}}}\right)^2 + \left(\frac{\delta \rho c_p}{\rho c_p}\right)^2} \quad (2.9)$$

The mains-side water temperatures were known to range from 9-30°C in most extreme cases, from the prior experience with the HXTP. Table 2-4 shows the water properties at extreme temperature ranges.

Table 2-4: Maximum and minimum range of expected water properties [28]

Temperature °C/K	Specific heat capacity $c_{p,c}$ kJ/kg.K	Density ρ_c kg/m ³
9°C/282.15K	4.19413	1000
30°C/303.15K	4.17837	995.76

In Equation 2.8, the ratio of maximum to minimum $\rho_c c_{p,c}$ was calculated based on the water properties in Table 2-4.

$$\frac{(\rho_c c_{p,c})_{\min}}{(\rho_c c_{p,c})_{\max}} = \frac{(\rho_c c_{p,c})_{30^\circ\text{C}}}{(\rho_c c_{p,c})_{9^\circ\text{C}}} = \frac{4160.65 \frac{\text{kJ}}{\text{m}^3\text{K}}}{4194.13 \frac{\text{kJ}}{\text{m}^3\text{K}}} = 99.2\%$$

The above calculation showed that there would be a maximum difference of 0.8% between the maximum and minimum calculated values of q_{flow} , if variable properties for density and specific heats were used. Since the difference was not significant, density and specific heat of water were assumed constant to be 997.6 kg/m³ and 4.18 kJ/kgK respectively for test method 1.

In Equation 2.9, $\delta\Delta T_{\text{cold}}$ and $\left(\frac{\delta\dot{V}_{\text{cold}}}{\Delta\dot{V}_{\text{cold}}}\right)$ were the uncertainty in RTD measurements and flowmeter as shown in Section 2.2.4. ΔT_{cold} was the difference between mains-side outlet and inlet temperature. $\left(\frac{\delta\rho c_p}{\Delta\rho c_p}\right)$ represented the percent error in the fluid properties and has been estimated to be 0.8% in this section.

Uncertainty was calculated for every one second time step for all tests. The maximum uncertainty value was estimated to be $\pm 2.60\%$ of the calculated q_{flow} values. The estimated uncertainty is applicable for all the calculated mains-side flow energy and heat transfer rates in this thesis. The uncertainty bars are only shown for the flow energy transfer rate plots in Chapter 3 of this thesis to demonstrate their application. The flow energy and heat transfer rate plots in the appendix section do not include uncertainty bars for clarity.

Chapter 3 Analysis, Results and Discussions for Test Method 1

3.1 Data Analysis for Test Method 1

All of the DWHR systems used in this thesis were provided by RenewABILITY Energy Inc. RenewABILITY DWHR systems are named based on the ID and length of the drain-side pipe. For example, a residential DWHR system with drain-side ID of 4" and drain-side length of 36" would be named as R4-36. The outer (mains-side) coils were the same for all DWHR systems. Outer coils loop around the drain-side in a set of 4 copper tubes. Mains-side coils on all DWHR systems used in this thesis were 1.5" ASTM B88 TYPE L copper tubes.

3.1.1 Shakedown Testing of DWHR Systems

Shakedown tests were performed to validate the generalized experimental approach. In particular, the shakedown tests were intended to determine if test conditions could be set as desired, and to ensure if the entirety of the test process was feasible. It was also intended to ensure the data would be suitable for analysis, and to ensure that the test process produced repeatable results.

In order to observe the temperature response, a DWHR system was tested. Temperature profiles for the randomly selected DWHR system at a random flowrate are shown in Figure 3-1. The DWHR was R3-48, tested at a flowrate of 7LPM. ΔT was the difference between the drain-side inlet (T_{hi}) and mains-side inlet (T_{ci}) temperatures. The uncertainty error bars calculated in Section 2.2.4 were relatively small as compared to the measured temperature readings. They are represented by the black markers on the temperature curves.

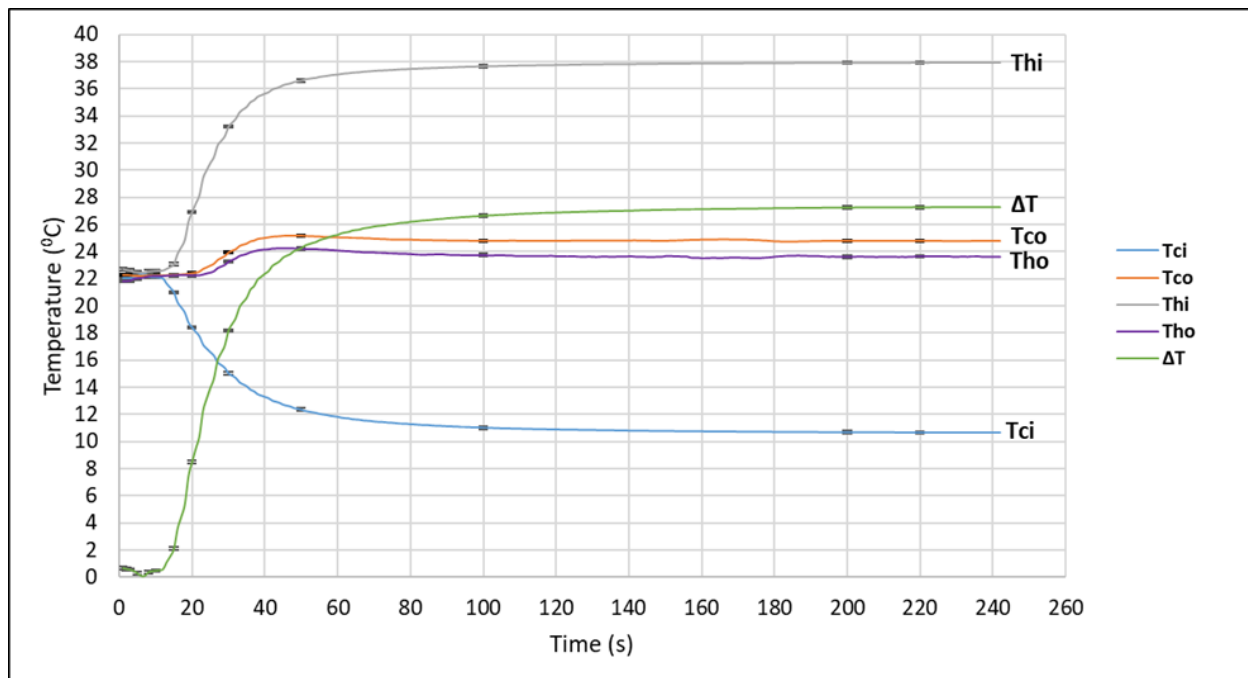


Figure 3-1: Shakedown test temperature profiles of R3-48 at 7LPM

Temperature responses from Figure 3-1 shows that at the start of the test, all the inlet and outlet temperatures were approximately at the ambient temperature conditions of about $22 \pm 2^{\circ}\text{C}$. Once the test was initiated and water flow began at 7LPM, no system temperatures changed for almost 15 seconds. The inlet temperature profiles started to diverge at the same time at 15 seconds, indicating that the mains and drain-side flows were reaching the DWHR system at approximately the same time. Mains and drain-side inlet temperatures became steady at around 120 seconds at 10 and 38°C respectively, which was the same as the pre-set inlet temperature conditions for all the tests. Mains and drain-side outlet temperatures reached steady temperatures of 25 and 24°C at about 160 seconds. The final steady outlet temperatures varied for each test based on the amount of induced heat transfer.

3.1.2 Repeatability of DWHR System Temperature Response

Repeatability is the closeness or agreement between the successive measurements obtained by different tests, when performed at the same input and ambient conditions. It is important to establish test repeatability during experimental work to provide confidence in the data collected. In case of DWHR systems, it means conducting tests at the same flowrate, along with the same inlet and ambient temperature conditions.

Since the transient analysis brings time into the equation, it is very important to make sure that repeatability between the measured quantities could be established for the entire test duration. The experimental approach would be completely invalid if repeatability wasn't established.

In order to determine repeatability, a random DWHR system was tested twice at the same flowrate and inlet temperature conditions. In this test, the system was R3-48 at the flowrates of 14 and 9LPM. The main focus was to observe how well the temperature profiles for both tests overlapped with each other. Each complete repeatability test consisted of running the random DWHR system at the flowrates of 14 and 9LPM. Figure 3-2 and Figure 3-3 shows the measured temperature profiles, after running the DWHR system 2 times at the same inlet conditions. Solid and dashed lines represents 2 different tests.

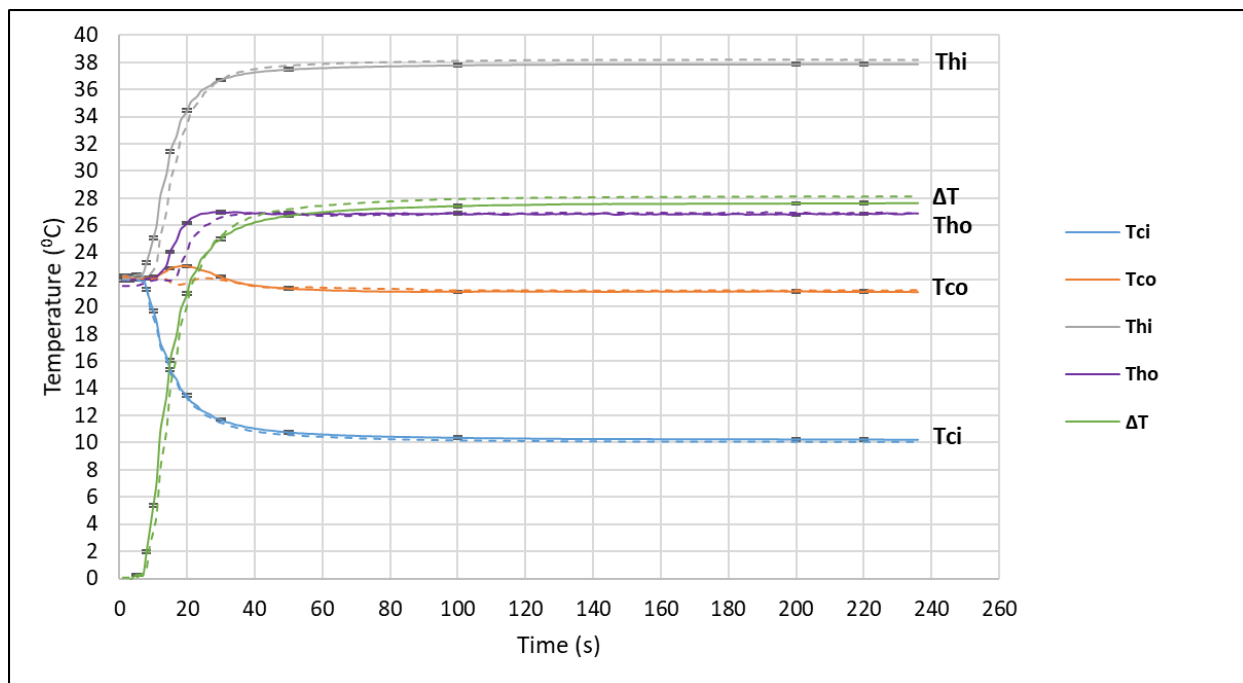


Figure 3-2: Repeatability of temperature profiles of R3-48 at 14LPM

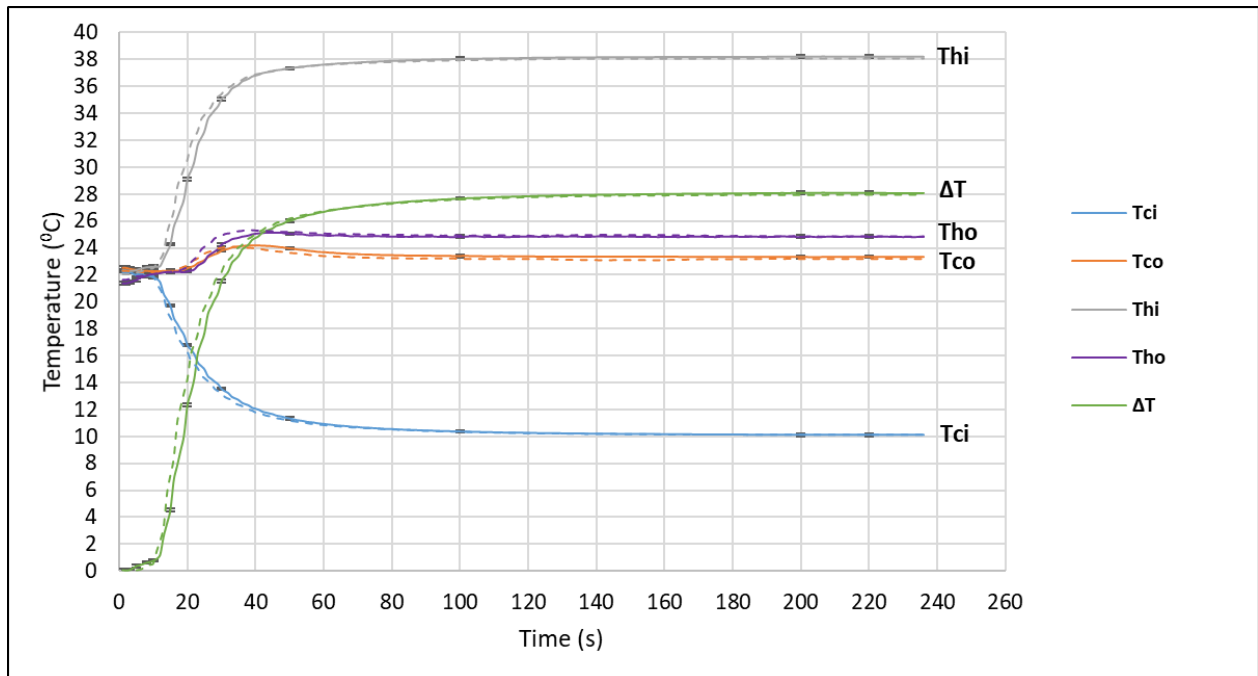


Figure 3-3: Repeatability of temperature profiles of R3-48 at 9LPM

For both the tests, the temperature profiles followed each other very closely. The slight deviations at the starting points in the transient portion were due to the inability to maintain the exact same ambient conditions for all of the tests. The ambient conditions in the lab drifted slightly all the time. The difference between both temperature profiles was under 4% for the majority of test duration. Since temperature profiles for both tests followed each other very closely, it was determined that excellent repeatability was achieved. Each temperature profile from both tests had the same shape during the beginning transient region, and reached steady-state at about the same time.

3.1.3 Removal of Unresponsive Time Periods

The unresponsive time periods estimated in Section 2.5.2 could be observed in Figure 3-1, Figure 3-2 and Figure 3-3, where the temperatures did not start to respond immediately once the experiments were initiated. All those figures showed that there was about a 10-15 second delay before any temperature response was observed. This delay was due to presence of water in the hoses and mains-side coils from previous tests, which had now reached ambient conditions. Temperature response would only be observed once all of the pre-existing water in the hoses and coils was cleared out and the conditioned water reached the inlet RTDs.

In order to compare the transient temperature response of different DWHR systems at different flowrates, it was necessary to make sure that the temperature profiles started to respond at the same time for all DWHR systems, after the water at ambient temperature had cleared out of DWHR system coils.

The best way to do that, was to remove the data for unresponsive time. A case is presented for R4-36 at 12LPM. Figure 3-4 shows the temperature profiles for R4-36 at 12LPM as plotted from the raw data. Based on the unresponsive time periods stated in Table 2-3, the first 9 seconds of data was eliminated from Figure 3-4.

After the removal of unresponsive time periods as seen in Figure 3-5, the zero-time point was reset at the location where the first response was observed in the inlet and outlet temperature profiles. This step enabled having the same starting point for all tests, which was required to be able to compare the temperature profiles for different cases.

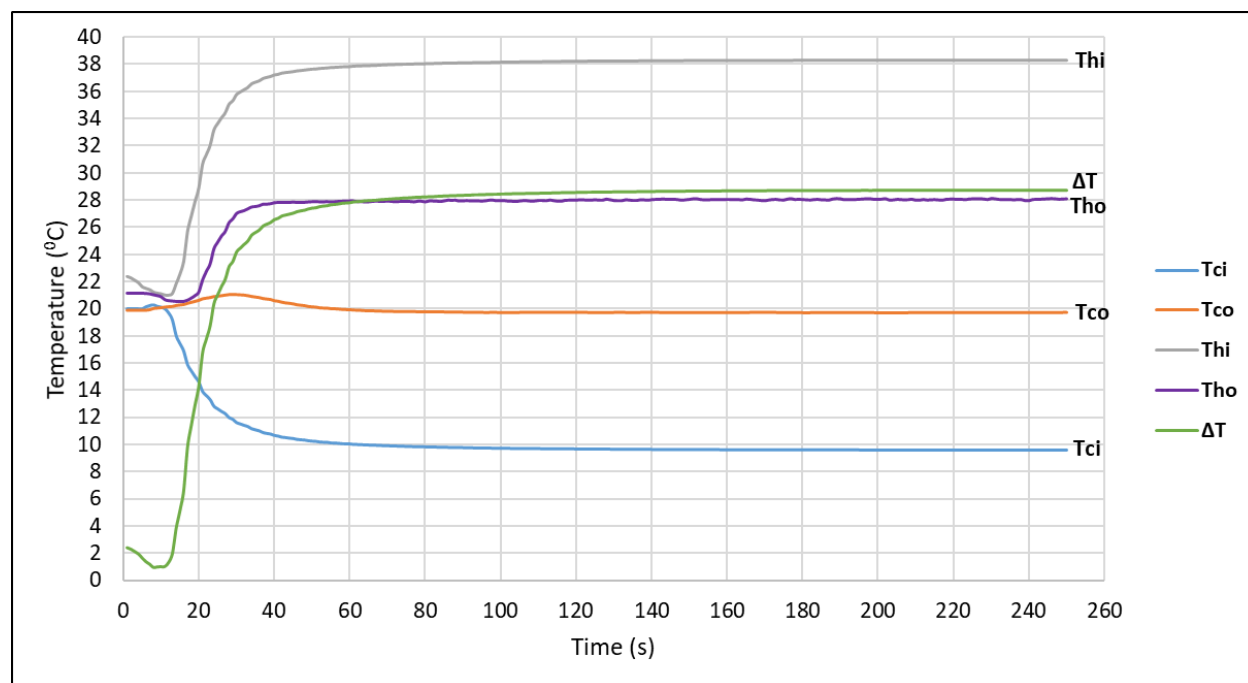


Figure 3-4: Original temperature response for R4-36 at 12LPM

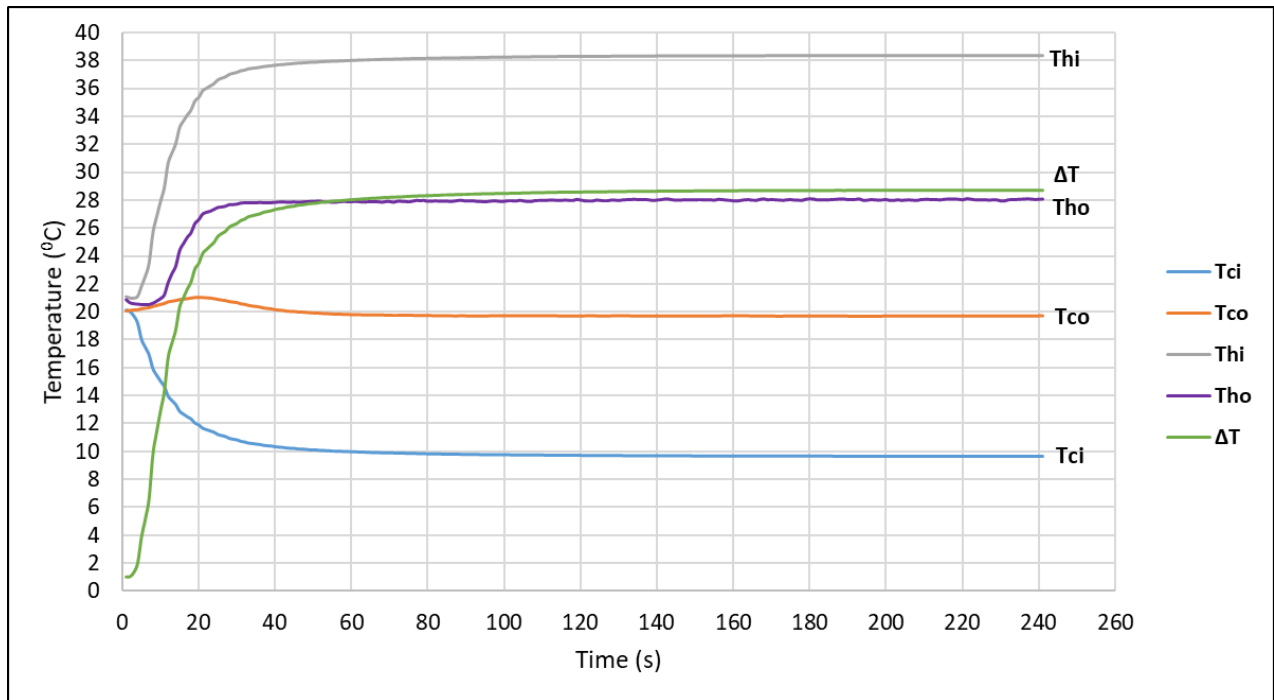


Figure 3-5: Corrected temperature response for R4-36 at 12LPM

From Figure 3-5, most of the temperature change was observed within the first 50 seconds of the corrected temperature response. For most of the test cases, a common diverging temperature point, close to T_{ambient} ($22 \pm 2^{\circ}\text{C}$) was observed, which resulted due to providing enough time (5-6 hours) for the HXTP to cool down.

3.2 Results for Test Method 1

3.2.1 Selection of Sample Sizes

In order to investigate q_{flow} and time responses, it was important to make sure that the selected sample size covered a range of DWHR systems. DWHR systems are usually available in the drain-side diameters of 2, 3 and 4". The drain-side length of the DWHR systems varied from 36" up to 84" with an increment of 12". STRL had DWHR systems of all available diameters but not all lengths. Table 3-1 shows the matrix of DWHR systems that were available and used for this investigation.

Table 3-1: Matrix of DWHR systems selected for determining transient response

		Length (INCHES)				
		36"	48"	60"	72"	84"
Diameter (INCHES)	2"	✓	✓	✓	X	X
	3"	✓	✓	✓	✓	✓
	4"	✓	✓	✓	X	X

Based on Table 3-1, 11 DWHR systems were tested. Each DWHR system was tested at all 6 CSA flowrates. About 4-5 minutes of raw data was collected for each of the tests. In total, 66 tests were conducted. Only 2 tests were conducted per day to make sure that the inlet and outlet temperatures, along with the HXTP could reach ambient room temperature conditions before the next test was initiated.

3.2.2 Estimation of Mains-Side Flow Energy Transfer Rate

The generalized approach consisted of determining the mains-side flow energy transfer rate (q_{flow}) of DWHR systems, by using the difference in the mains-side outlet and inlet temperature as shown in Equation 2.4, which was further converted to Equation 2.8.

The main purpose of this section is to show the results of the generalized test procedure along with establishing some information about q_{flow} during the transient portions of any DWHR related experiment. The time responses of the DWHR systems could then be determined based on the nature of q_{flow} and the time taken to reach quasi-steady conditions.

It is important to note that the nature of the observations and conclusions made in this section were similar for all the cases. Hence, any conclusions made for the demonstrated sample were applicable to all the test cases.

Test case of R4-36 at 12LPM was used for calculation and demonstration purposes. Table 3-2 shows a sample of collected data, along with the estimated q_{flow} values for R4-36 at 12LPM. The calculation sample below is shown for the time, $t = 132(\text{s})$ after the temperature profiles started to respond. q_{flow} calculation procedure was exactly the same for all of the tests conducted.

Table 3-2: Processed data sample for R4-36 at 12LPM

Time (s)	T _{ci} (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow Rate LPM	T _{co} -T _{ci} (°C)	q _{flow} (kW)
7	16.89	20.29	23.51	20.54	11.69	3.4	2.7623
8	15.91	20.38	25.67	20.63	11.76	4.47	3.6534
9	15.44	20.45	26.83	20.79	11.89	5.01	4.1400
10	15.02	20.52	27.91	20.97	11.99	5.5	4.5831
11	14.62	20.6	28.92	21.24	12.03	5.98	4.9997
12	13.93	20.71	30.67	22.13	12.15	6.78	5.7252
13	13.62	20.76	31.37	22.76	12.15	7.14	6.0291
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
130	9.67	19.71	38.27	28.01	11.99	10.04	8.3663
131	9.67	19.71	38.27	28.05	11.99	10.04	8.3663
132	9.66	19.71	38.27	28.07	11.99	10.05	8.3747
133	9.66	19.71	38.28	28.08	11.98	10.05	8.3677
134	9.66	19.7	38.28	28.09	11.98	10.04	8.3593

Constant values for density and specific heat capacity of water has been assumed in Section 2.5.4. Hence, the only unknown parameter from Equation 2.8 was volumetric flowrate \dot{V} , which was calculated from the CSA flowrate as follows:

$$11.99 \frac{\text{L}}{\text{min}} \times \frac{1 \text{ m}^3}{1000 \text{ L}} \times \frac{1 \text{ min}}{60 \text{ s}} = 0.0001998 \frac{\text{m}^3}{\text{s}}$$

Substituting all known values in Equation 2.8 yielded:

$$q_{\text{flow}} = 997.6 \frac{\text{kg}}{\text{m}^3} \times 4.18 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \times 0.0001998 \frac{\text{m}^3}{\text{s}} \times (19.71 - 9.66) \text{K} = 8.3747 \text{ kW}$$

Two different plots of q_{flow} including uncertainty bars, with respect to time for R4-36 and R3-36 at all flowrates, which were representative of the entire data set are shown in Figure 3-6 and Figure 3-7 . Both figures show that the response time is DWHR system dependent. The plots for all other DWHR systems are shown in Appendix A. Full results are summarized later in the current chapter. Based on the shape of both the plots, it was assumed that the DWHR systems behaved as first order systems.

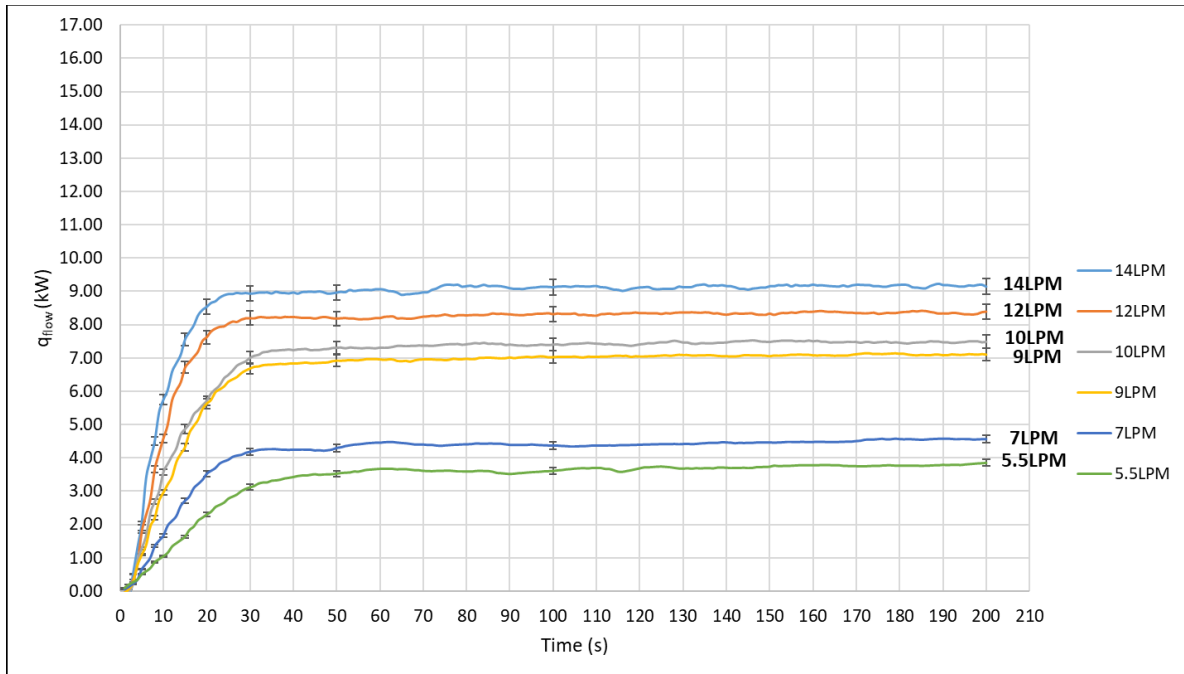


Figure 3-6: Calculated mains-side flow energy transfer rate for R4-36

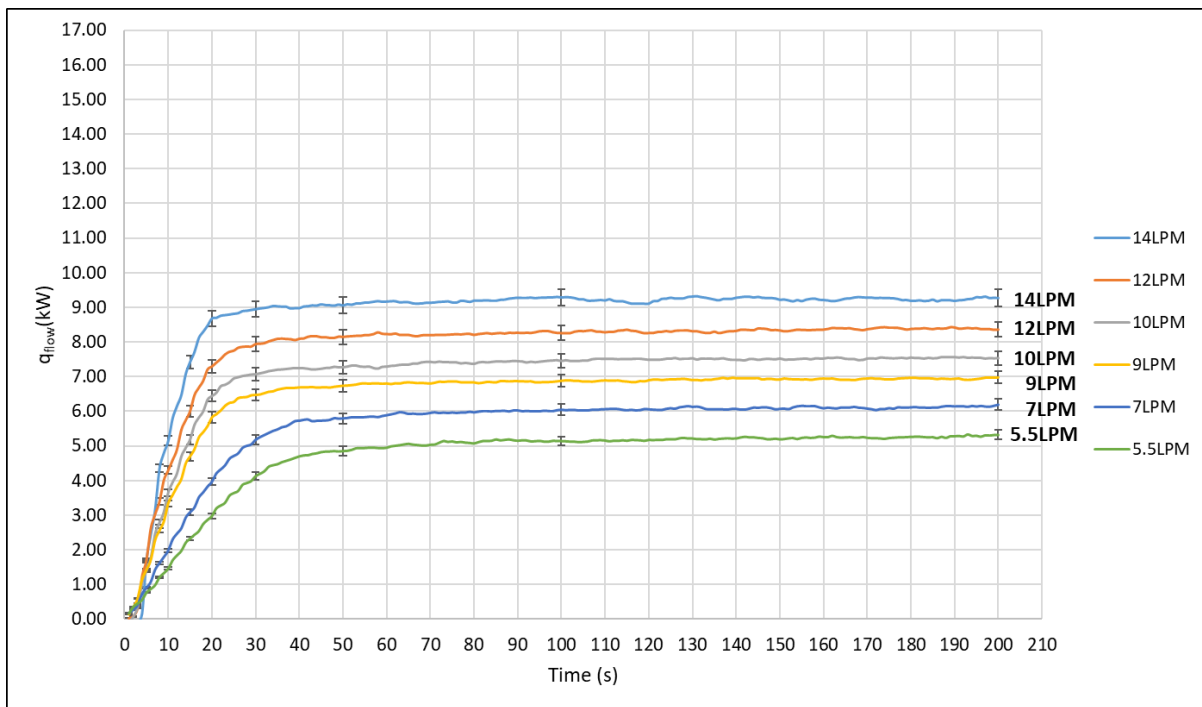


Figure 3-7: Calculated mains-side flow energy transfer rate for R3-36

Flowrate and flow energy transfer rate (q_{flow}) increased and decreased in the same direction. The highest q_{flow} was associated with 14LPM. Based on that observation, q_{flow} at 12LPM was represented in the colour red as the 2nd flow energy transfer rate curve from the top.

Even though lower flowrates generally result in higher mains-side outlet temperatures, the volumetric flowrate in Equation 2.8 seems to have a much stronger impact on q_{flow} , as compared to the temperature difference on the mains-side entry and exit. The energy balance performed in this section to calculate q_{flow} , did not take into account any heat losses or heat transfer to the surrounding copper pipe. Moreover, no DWHR system energy storage was taken into account.

Figure 3-6 and Figure 3-7 showed that q_{flow} profiles for all 6 flowrates had the same shape, which started with a sharp increase and eventually reached quasi-steady-state. Most of the change in q_{flow} was observed before the first 50 seconds.

The flow energy transfer rate only reached quasi-steady-state conditions when it was relatively stable and didn't increase or decrease significantly in magnitude. This was evident from slight fluctuations in the steady-state region where q_{flow} lines were almost horizontal. Even the measured raw data had slight fluctuations in the flowrate and inlet and outlet temperatures at steady-state operating conditions as well. The RTD and flowmeter readings were only accurate to 2 decimal places. All these factors had an impact on the calculated uneven readings of q_{flow} .

Figure 3-6 and Figure 3-7 also showed that the time taken for q_{flow} to stabilize was inversely related to flowrate. For faster flowrates, it would take less time to reach quasi-steady-state conditions, as the mains-side coils were able to get rid of the ambient water much faster and responded to incoming mains and drain-side water.

3.2.3 Estimation of Thermal Time Response

The flow energy transfer rate (q_{flow}) was used to determine the thermal time response for all the test cases because of its exponential nature as seen from Figure 3-6 and Figure 3-7. A constant magnitude of q_{flow} wasn't established due to experimental fluctuations.

The 99% and 95% steady-state response times could not be established directly due to the uneven nature of q_{flow} curves during steady-state operation. Since q_{flow} increased rapidly during the beginning phase of the test before it reached quasi-steady-state conditions, it was decided to estimate the lower order thermal time response of DWHR systems. Due to the unpredicted nature of q_{flow} around the steady-state mark, 63.2% and 86.5% steady-state time

responses were determined for all the tested DWHR systems. 63.2% time response is a good representation of the first time constant in transient systems [29].

Sample calculations were only shown for the derivation of 63.2% time responses. The calculation procedure and derived conclusions for 63.2% time response were fully applicable for 86.5% response as well. All of the relevant derived results for 86.5% response are presented in Appendix C.

Time response derivation was also shown for a single case of R4-36 at the flowrate of 12LPM. q_{flow} was relatively stable and steady after the 2 minute mark for all the tests. Hence, in order to estimate a constant steady-state value for mains-side flow energy transfer rate, average of q_{flow} was taken for all data points after the 3rd minute mark. This was done to make sure that the values being averaged were completely around the steady-state. The averaged value of q_{flow} after bypassing 3 minutes of data would serve as the steady-state reference point, around which the 63.2% and 86.5% time responses were estimated for all the tests. A portion of the averaged data for the sample calculation case is shown in Table 3-3.

Table 3-3: Portion of averaged mains-side flow energy transfer rate for R4-36 at 12LPM

Time (s)	$T_{\text{co}} - T_{\text{ci}}$ (°C)	$q_{\text{flow,SS}}$ (kW)
181	10.07	8.3843
182	10.07	8.3843
183	10.07	8.4123
184	10.07	8.3983
185	10.07	8.4193
⋮	⋮	⋮
238	10.08	8.3086
239	10.09	8.3238
240	10.09	8.3519
241	10.09	8.3449

The averaged steady-state value of q_{flow} was therefore computed as:

$$q_{\text{flow,SS}} = \frac{8.3843 + 8.3843 + \dots + 8.3519 + 8.3449}{241 - 181} = 8.3669\text{kW}$$

From the averaged steady-state flow energy transfer rate, 63.2% response time was derived as follows:

$$q_{\text{flow,63.2\%}} = 0.632(q_{\text{flow,SS}})$$

$$q_{\text{flow},63.2\%} = 0.632(8.3669) = 5.2879\text{kW}$$

From Table 3-2, it was observed that q_{flow} at 63.2% time response was between 11 and 12 seconds. Since data was acquired after 1 second intervals, it was not possible to determine the exact response time to the fraction of a second. An approximation was made by linear interpolation during the selected time interval.

$$\frac{t_{63.2\%} - 11}{12 - 11} = \frac{5.2879 - 4.9997}{5.7252 - 4.9997}$$

$$t_{63.2\%} = 11.40 \text{ seconds} \approx 12 \text{ seconds}$$

The final response time was estimated to be around 12 seconds by rounding up to the nearest number. The mains-side flow energy transfer rates and 63.2% thermal time responses for all the DWHR systems and tests conducted are shown in Table 3-4.

Table 3-4: Summarized mains-side flow energy rate and 63.2% time responses

	14LPM			12LPM			10LPM		
	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)
R2-36	7.0634	4.4641	12.09	6.5590	4.1453	10.60	5.8895	3.7222	9.50
R2-48	9.3638	5.9179	6.57	8.7810	5.5496	8.541	7.7948	4.9263	10.89
R2-60	10.5090	6.6417	10.15	9.5071	6.0085	13.94	8.4508	5.3409	13.94
R3-36	9.2588	5.8516	11.17	8.3857	5.2998	12.71	7.5334	4.7611	13.25
R3-48	10.6157	6.7091	6.3499	9.9115	6.2641	10.35	8.7781	5.5478	12.03
R3-60	12.2646	7.7512	11.54	11.3902	7.1986	12.74	9.8698	6.2377	14.14
R3-72	13.5054	8.5354	13.04	12.2686	7.7538	15.67	10.7084	6.7677	19.01
R3-84	15.7138	9.9311	14.84	13.8137	8.7302	17.52	12.2496	7.7417	19.85
R4-36	9.1926	5.8097	10.21	8.3669	5.2879	11.40	7.4888	4.7329	14.20
R4-48	12.1702	7.6915	8.2758	11.0910	7.0095	9.273	9.7894	6.1869	9.231
R4-60	13.1833	8.3318	15.07	12.2273	7.7277	14.67	10.7212	6.7758	17.15
	9LPM			7LPM			5.5LPM		
	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)	q _{flow, SS} (kW)	q _{flow, 63.2%} (kW)	t _{63.2%} (s)
R2-36	5.4296	3.4315	15.02	4.7779	3.0197	14.90	4.0817	2.5797	23.35
R2-48	7.3167	4.6242	8.123	6.0842	3.8452	13.01	5.2565	3.3221	20.56
R2-60	7.8195	4.9419	15.32	6.5915	4.1658	20.53	5.5835	3.5288	28.39
R3-36	6.9465	4.3902	13.76	6.1160	3.8653	19.28	5.2744	3.3334	22.66
R3-48	8.2330	5.2033	12.49	6.9507	4.3928	13.86	6.0107	3.7988	21.63
R3-60	9.3487	5.9084	16.88	7.9195	5.0051	21.87	6.7050	4.2376	26.66
R3-72	10.0905	6.3772	20.66	8.3953	5.3058	27.37	7.0852	4.4779	31.81
R3-84	11.2903	7.1355	22.21	9.2137	5.8231	24.72	7.5622	4.7793	37.69
R4-36	7.0996	4.4870	15.38	4.5884	2.8999	16.23	3.8422	2.4283	21.32
R4-48	9.2791	5.8644	11.43	7.5757	4.7878	15.63	5.9036	3.7311	19.61
R4-60	10.1566	6.4189	19.60	8.1510	5.1514	24.34	4.8278	3.0511	21.74

3.3 Discussions for Test Method 1

3.3.1 Limitations of Test Results

One of the major problems faced during conducting the experiments was the unavailability of some of the DWHR system dimensions as shown in Table 3-1. A complete set of DWHR system lengths were only available for the 3" drain-side diameter. Secondly, when the estimated time responses were compared against the drain-side diameters of 2, 3 and 4", no relationship was observed. A relationship of time response as a function of diameter couldn't be defined with 3 only data points. Hence, it was not possible to convey how the drain-side diameter would impact the time response of the selected DWHR systems.

Larger drain-side diameters would result in more surface area available for heat transfer and a higher thermal mass. Hence, the DWHR systems with larger diameters would take a longer time to stabilize and reach steady-state. This could be verified if DWHR systems with drain-side diameters larger than 4" were available.

3.3.2 Relationship between Time Response and CSA Flowrate

CSA flowrates were used to understand the behaviour of the estimated time responses. Data from Table 3-4 was used to determine the impact of CSA flowrates on the estimated time responses. Figure 3-8 to Figure 3-10 shows the plots for 63.2% thermal time responses as a function of CSA flowrates, for all the DWHR systems used in this experiment.

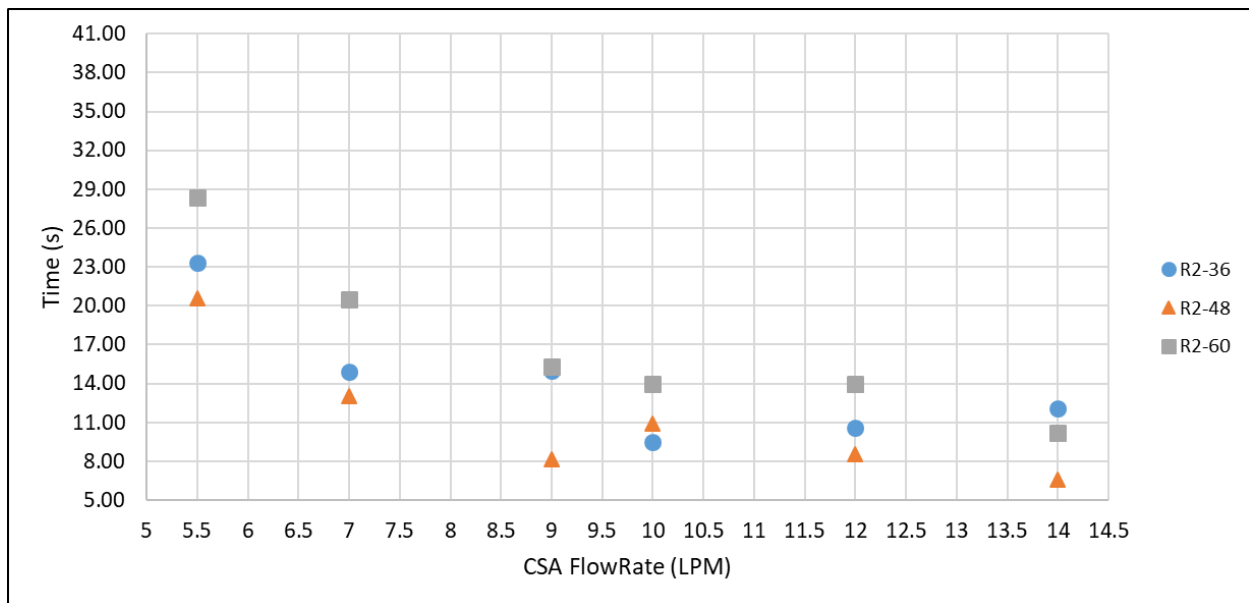


Figure 3-8: Experimental 63.2% time response vs CSA flowrate of 2" drain-side diameter DWHR systems

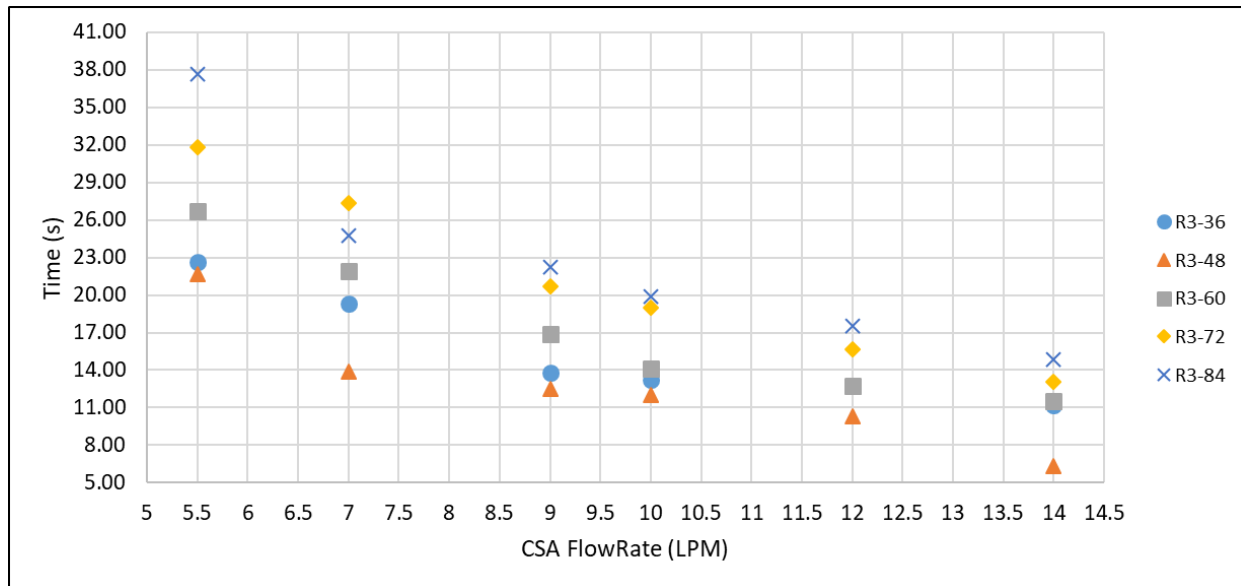


Figure 3-9: Experimental 63.2% time response vs CSA flowrate of 3" drain-side diameter DWHR systems

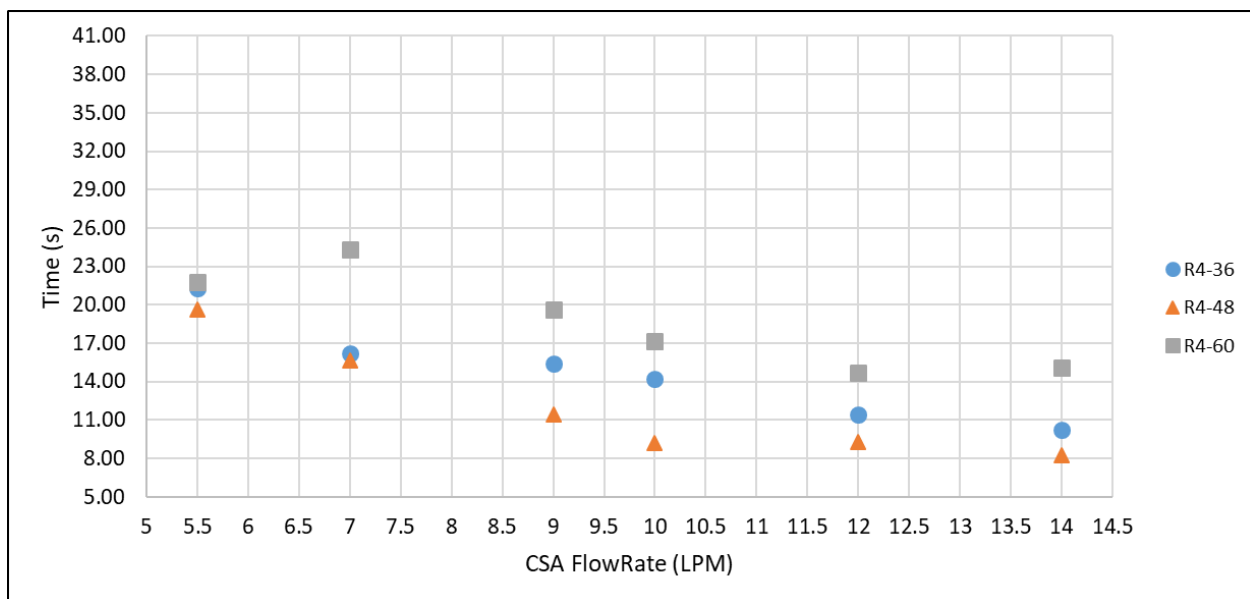


Figure 3-10: Experimental 63.2% time response vs CSA flowrate of 4" drain-side diameter DWHR systems

All of the 3 figures above showed that in most cases, the 63.2% time response generally decreased with increasing flowrate. This was because at higher flowrates, any pre-existing water at ambient conditions that was present in the mains-side coils would clear out faster. Hence, the conditioned incoming water entered the coils in a shorter period of time, and the DWHR system would start to stabilize and reach steady-state more quickly. This was the general pattern, which was observed for most of the DWHR systems that were tested. It was observed that the transient response time was highly dependent on DWHR systems and hence could be a reason for slight

deviations from the patterns observed. The measurement and estimation of the response time was approximate.

Based on the time responses established, linear fit could describe the relationship between time response and flowrates. The relationships established for all 11 DWHR systems were of the form shown in Equation 3.1.

$$t_{63.2\%} = A\dot{V}_{CSA} + B \quad (3.1)$$

Where \dot{V}_{CSA} was the CSA flowrate in LPM. A and B were the coefficients for each specific DWHR system. Figure 3-11 shows the experimental and correlated values for one of the DWHR systems. Coefficients of Equation 3.1 for all 11 DWHR systems are shown in Table 3-5. Plots for the 63.2% experimental and correlational time responses for all of the 11 DWHR systems are presented in Appendix B.

Table 3-5: Correlation coefficients for all DWHR systems as a function of CSA flowrate

	A $\frac{s}{\left(\frac{L}{min}\right)}$	B s	R²
R2-36	-1.21	25.86	0.5809
R2-48	-1.38	24.54	0.7310
R2-60	-1.90	35.27	0.8447
R3-36	-1.32	28.09	0.8516
R3-48	-1.49	27.07	0.8581
R3-60	-1.78	34.36	0.9025
R3-72	-2.22	42.54	0.9594
R3-84	-2.33	45.12	0.8189
R4-36	-1.21	26.36	0.9205
R4-48	-1.31	24.76	0.8400
R4-60	-1.10	29.26	0.8023

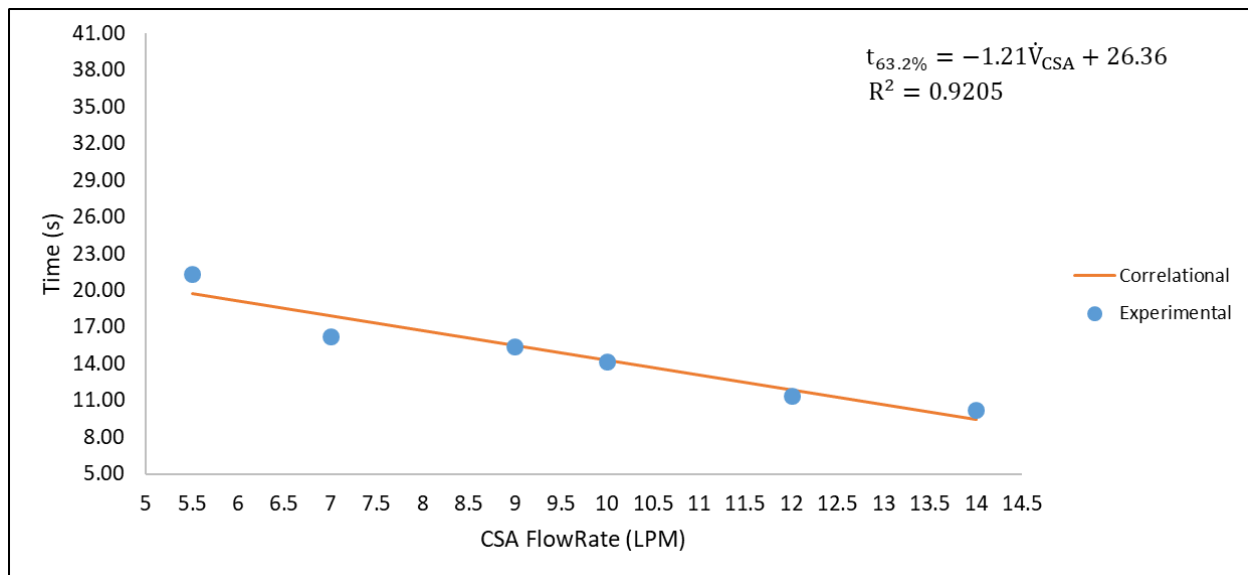


Figure 3-11: Experimental and correlational time response of R4-36 at different flowrates

The difference between the actual experimental time responses in Table 3-4 and the correlational time responses, were found by substituting the CSA flowrates into Equation 3.1 for all the DWHR systems, and then by finding the difference between both values. Table 3-6 shows the differences for R4-36.

Table 3-6: Difference between experimental and correlational time response of R4-36 at CSA flowrates

Flowrate LPM	R4-36		
	Experimental (s)	Correlational (s)	Δt (s)
14	10.21	9.42	0.79
12	11.40	11.84	-0.44
10	14.20	14.26	-0.06
9	15.38	15.47	-0.09
7	16.23	17.89	-1.66
5.5	21.32	19.71	1.62

3.3.3 Relationship between Time Response and Drain-Side Length

Only the 3" drain-side diameter DWHR systems had a bigger sample set of 5 and were used to establish trends for time response as a function of drain-side length. For both 2" and 4" diameter DWHR systems, no such trends could be established. Figure 3-12 shows the plot of the estimated time responses for 3" drain-side diameter DWHR systems from Table 3-4, when compared with drain-side length.

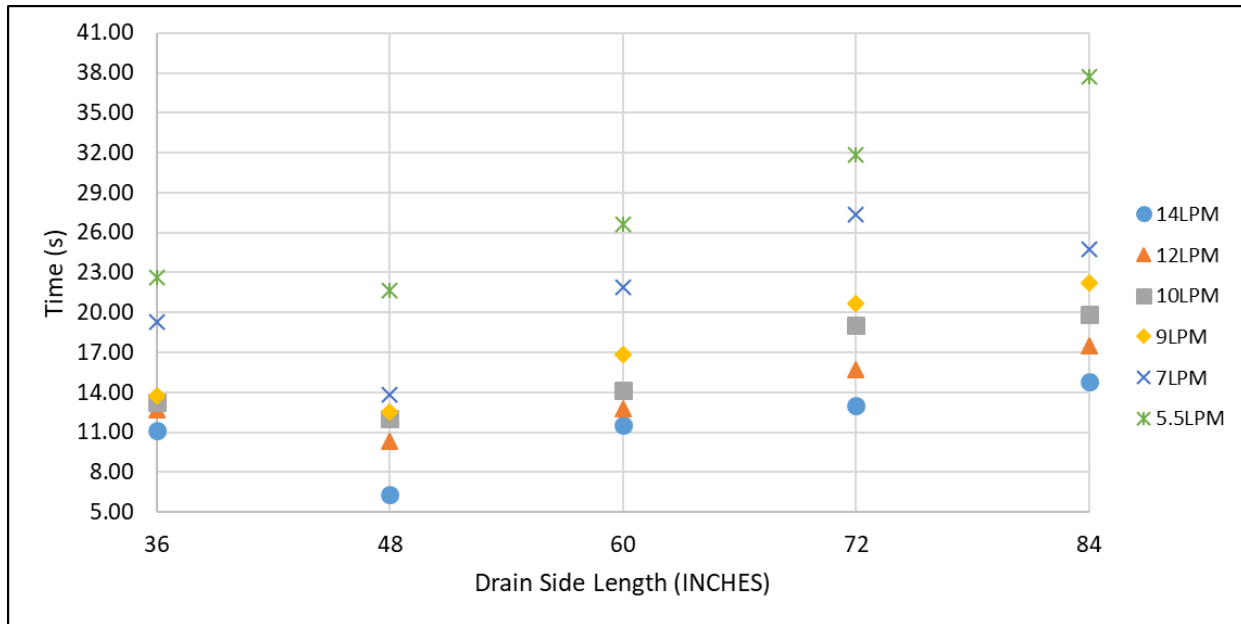


Figure 3-12: Experimental 63.2% time response vs drain-side length of 3" drain-side diameter DWHR systems at CSA flowrates

Figure 3-12 indicated that the time response generally increased for longer drain-side lengths at all flowrates. The key point in understanding this relationship was the fact that the DWHR systems with longer drain-side lengths had more coils. Hence, at a particular flowrate, as the drain-side length increased, any pre-existing water in the coils had to travel a longer distance to exit the DWHR system.

Even though a general increasing trend was observed, R3-48 behaved slightly differently at all flowrates. The time response was generally lower for R3-48 as compared R3-36. This could have been due to any unnoticeable manufacturing defects (specific to DWHR system) that might be present. No other exact same R3-48 was available in the lab to investigate this issue. The only other unexplained discrepancy in the data trend was observed for R3-84 at 7LPM, which could have resulted from experimental error and could be corrected if the same test is repeated again in the future.

Even for this case, a linear fit gave the best results when comparing time response to the drain-side length. The relationship between drain-side length and time response was of the form shown in Equation 3.2.

$$t_{63.2\%} = ML_{DS} + N \quad (3.2)$$

Figure 3-13 shows the plot of experimental and correlational time responses of all 3" diameter DWHR systems. In the above equation, L_{DS} represented the drain-side length in inches,

whereas M and N were the coefficients specific to particular CSA flowrates. All of the coefficients for the above equation are stated in Table 3-7.

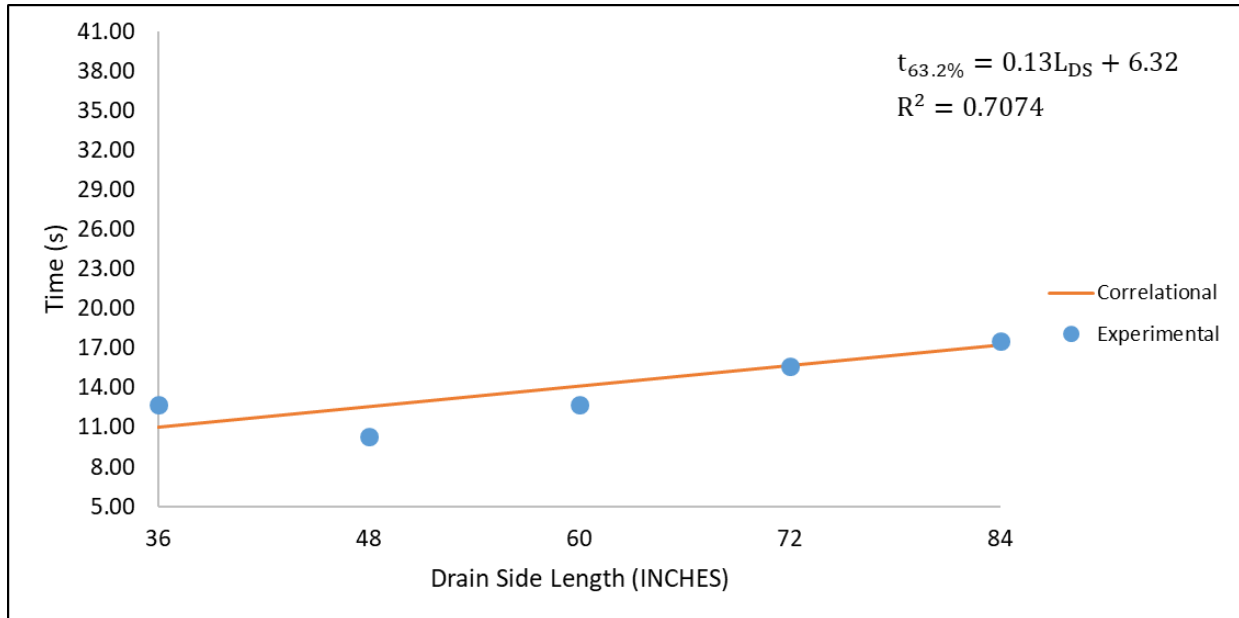


Figure 3-13: Experimental and correlational time response at 12LPM for all 3" drain-side diameter DWHR systems

Table 3-7: Correlation coefficients for all 3" drain-side diameter DWHR systems as a function of drain-side length

Flowrate LPM	M $\frac{s}{in}$	N s	R ²
14LPM	0.12	4.37	0.4912
12LPM	0.13	6.32	0.7074
10LPM	0.17	5.57	0.8133
9LPM	0.21	4.67	0.8824
7LPM	0.20	9.22	0.5502
5.5LPM	0.34	7.97	0.9036

The correlational time response at different flowrates and the time differences were found using Equation 3.2 and Table 3-7. Table 3-8 shows the difference between the experimental and correlational time responses at 12LPM for different 3" diameter DWHR systems.

Table 3-8: Difference between experimental and correlational time response at 12LPM for 3" drain-side diameter DWHR systems

DrainSide Length (INCHES)	12LPM		
	Experimental (s)	Correlational (s)	Δt (s)
36	12.71	11.00	1.71
48	10.35	12.56	-2.21
60	12.74	14.12	-1.38
72	15.67	15.68	-0.01
84	17.52	17.24	0.28

3.3.4 Relationship between Time Response and DWHR System Mass

The relationship between time response and DWHR system mass was briefly investigated, since it was exactly the same as the relationship between time response and drain-side length as shown in Section 3.3.3. The only difference would be in the x-axis of Figure 3-12 and Figure 3-13, which would be replaced by the mass of DWHR system. The overall shape of the curve would stay the same because the magnitude of the measured time responses did not change.

The time response was expected to increase because as the mass of the DWHR system increased, it would take more thermal energy to reach quasi-steady-state conditions. More energy and time would be required to firstly heat up the DWHR system, and then the mains-side water flowing in the coils.

Since the shape of the curve would be exactly the same as compared to drain-side length, linear equations similar to Equation 3.2 would be used to describe the best fit. The only difference would be between the correlation coefficients as compared to Table 3-7.

3.4 Validation of Derived Results

Validation of the derived results is an important part of any experimental research. It is important to note that a combined correlation for time response as a function of both flowrate and drain-side length couldn't be developed. The major reason was due to the uncontrolled instability that arose during the beginning transient portion of any test. Hence, validation of correlations developed for flowrate and drain-side length in Section 3.3.2 and Section 3.3.3, were performed separately to determine how well they could be used to predict 63.2% time response under a specified set of conditions.

3.4.1 Validation of Drain-Side Length Based Correlations for 3" Diameter DWHR systems

In order to validate the correlations developed for different drain-side lengths of 3" drain-side diameter DWHR systems at different CSA flowrates, arbitrary tests were conducted at standard CSA flowrates, and the predicted time responses were compared to the measured experimental time responses. The procedure for correlation validation was exactly the same as Section 3.3.3.

A total of 13 different test points were used for the purpose of validation, which included testing 2 DWHR systems at all 6 CSA flowrates and also performing some tests on other 3" drain-side diameter DWHR systems. Not all of the 3" drain-side diameter DWHR systems were tested again due to the timing constraint posed by transient analysis, which required leaving the HXTP idle for a long period of time. Table 3-9 shows the validation data for some cases of 3" drain-side diameter DWHR systems.

All of the linear equations coefficients to calculate the time response as a function of drain-side length are shown in Table 3-7. The method for calculation of the experimental time response was exactly the same as shown from Section 3.2.2 to 3.2.3 by using the acquired raw data. The procedures for removing unresponsive temperature periods and time interpolation were all performed in the same way.

Table 3-9: Correlation validation for 3" drain-side diameter DWHR systems as a function of drain-side length

	Flowrate (LPM)	Measured		Predicted	Δt (sec)	% error	$t_{99\%}$ (sec)
		q_{flow} (kW)	$t_{63.2\%}$ (sec)	$t_{63.2\%}$ (sec)			
R3-36	14	5.7119	9.81	8.69	1.12	11.42%	44.67
	12	5.3662	11.82	11.00	0.82	6.94%	52.96
	10	4.7942	15.51	11.69	3.82	24.63%	54.34
	9	4.4417	15.97	12.23	3.74	23.42%	57.56
	7	3.9275	21.05	16.42	4.63	22.00%	90.72
	5.5	3.3076	21.68	20.21	1.47	6.79%	105.00
R3-48	14	6.8826	8.68	10.13	-1.45	-16.71%	27.17
	12	6.3449	9.58	12.56	-2.98	-31.11%	43.75
	10	5.6085	10.43	13.73	-3.30	-31.64%	56.18
	9	5.2140	10.09	14.75	-4.66	-46.18%	62.17
	7	4.4885	17.04	18.82	-1.78	-10.45%	72.76
	5.5	3.7804	21.09	24.29	-3.20	-15.17%	122.04
R3-60	14	7.9570	11.25	11.57	-0.32	-2.84%	48.81
	7	4.9815	21.83	21.22	0.61	2.79%	108.22
R3-72	12	7.8114	14.82	15.68	-0.86	-5.80%	71.84

It was observed from Table 3-9 that the maximum deviation in the measured and predicted time response was less than 3 seconds. In any practical scenario, the transient response can never achieve 100% accuracy between the measured and estimated values. This is due to the unpredicted nature of transient experiments. Hence, a difference of a few seconds was reasonable for such types of estimations. This was the main reason why the percent error between the measured and predicted time response was higher in some cases. Another reason for a higher percent error was due to the smaller magnitude of the measured $t_{63.2\%}$ time response as compared to the Δt term.

Since transient response represented a very small portion of any DWHR system testing, the difference of a few seconds between the measured and predicted time responses would not be significant. Hence, it could be established that the correlations developed could predict the 63.2% steady-state time response for 3" diameter DWHR systems within reasonable accuracy of a few seconds.

3.4.2 Validation of Flowrate Based Correlations

The validation of flowrate based correlations for different DWHR systems was completed using the same methodology as Section 3.4.1. The exact same procedure was followed except the linear equations whose coefficients were derived from Table 3-5. All of the cases for validation are summarized in Table 3-10.

Table 3-10: Correlation validation for different DWHR systems as a function of flowrates

	Flowrate (LPM)	Measured		Predicted	Δt (sec)	% error	$t_{99\%}$ (sec)
		q_{flow} (kW)	$t_{63.2\%}$ (sec)	$t_{63.2\%}$ (sec)			
R3-48	6.07	4.1022	24.1	18.03	6.07	25.19%	92.10
	11.35	6.1244	13.16	10.16	3.00	22.80%	57.56
R2-48	13.67	5.9884	10.17	5.68	4.49	44.15%	41.91
	9.36	4.7618	14.24	11.62	2.62	18.40%	60.33
R4-60	8.98	6.4188	20.32	19.38	0.94	4.63%	89.80
	7.96	5.9066	22.00	20.50	1.50	6.82%	99.93
R3-72	12.08	7.8114	14.82	15.72	-0.90	-6.07%	64.47
	7.55	5.5686	23.69	25.78	-2.09	-8.82%	92.10
R2-60	11.27	5.7809	13.37	13.86	-0.49	-3.66%	58.49
	9.36	5.0307	16.00	17.49	-1.49	-9.31%	68.62
R4-36	9.01	4.4071	13.85	15.46	-1.61	-11.62%	62.63
	7.06	3.6545	20.59	17.82	2.77	13.45%	92.10

The maximum deviation between measured and predicted time responses was around 5 seconds. Uncertainty would always be present in any type of transient experiments. The larger % error arose from the same reasons stated in the previous sub-sections.

3.4.3 Limitations of Test Method 1

The major limitation of test method 1 was the inability to directly calculate the 99% time response from the experimental data, as stated in Section 3.2.3. The only way to estimate $t_{99\%}$ was by fitting the first order exponential equation, of the form shown in Equation 3.3, to q_{flow} vs time plots.

$q_{flow,SS}$ would be calculated in the same way as shown in Section 3.2.3. τ_{flow} represents the flow energy time constant which would be varied to obtain a good fit. Once the best possible first order exponential equation was derived, $t_{99\%}$ would be estimated by substituting 99% of $q_{flow,SS}$ in Equation 3.3.

$$q_{flow} = q_{flow,SS} \left(1 - e^{\frac{-t}{\tau_{flow}}} \right) \quad (3.3)$$

The last column of Table 3-9 and Table 3-10 shows the estimated steady-state time response ($t_{99\%}$) for some of the cases. Both the tables shows that the complete steady-state was reached around 2 minutes for the lowest flowrates.

Secondly, having a unique correlation for each test condition is another limitation of test method 1. This approach was also used by Gao et al. [18], where second order polynomial equations for temperature responses were developed as a function of time, for each unique case of cross flow heat exchangers. Since it has been established in this chapter that transient effects occur during the earliest phases of a transient test, the correlations developed could provide a good approximation of estimated time response for different DWHR systems.

Another limitation of this test method was the inability to determine the energy storage effects shown in Equation 2.3. Since storage effects play a crucial role during the beginning phases of a test due to quick temperature responses, they must be included when heat transfer rates are calculated for DWHR systems. This is the scope for the second test method.

Chapter 4 Test Method 2

4.1 Background

The generalized approach (test method 1) discussed in Chapter 2 only focused on the mains-side inlet and outlet temperatures to estimate q_{flow} . Test method 2 includes the use of infrared thermography, which can provide the surface temperature profiles across the entire DWHR system.

In general, the rate of heat addition and water temperature change across DWHR length have not been studied extensively. The ability of test method 2 to determine surface temperatures, would lead to the estimation of mains-side water temperature across the entire DWHR system length, and in turn estimating the mains-side heat transfer rate (q_c) in Equation 2.3, by including energy storage effects (q_{storage}).

4.2 Initial Equipment Selection

Due to the geometry and design of DWHR systems, it was impossible to directly measure the temperature of water inside the coils. RTDs or thermocouples could not be inserted through the copper tube walls without interfering with the heat transfer characteristics, or increasing the risk of leakage.

This is the reason why the mains-side temperature measurement has been limited at water inlet and outlet points. Since DWHR systems are made completely of copper, which has high thermal conductivity of about 401 W/mK [30], surface temperature measurements at different locations across the length could provide some useful insight at the fluid temperature inside the mains-side coils. Using an infrared thermography camera was determined to be an excellent option available to conduct such an analysis, due to its ability to instantaneously resolve the temperature profile of the entire surface of DWHR systems.

Even though thermal camera was a great choice, it has issues related to emissivity and accuracy. Thermal cameras are very sensitive to its surrounding environment and any improper emissivity settings can have a severe impact on the measured temperature readings. Hence, thermocouples were also added at points to verify the temperatures being measured by the thermal camera itself. In order to investigate the water temperature versus surface temperature,

two thermocouples were placed near the mains-side inlet and outlet along with the immersion RTDs and provided a good comparison between temperature readings. Hence, the main equipment used for thermography included a thermal camera and thermocouples. More details about the equipment used is presented in upcoming sections.

The measurement method proposed for the mains-side surface temperature consisted of using Type T thermocouples made of copper and constantan. Type T are one of the most common types of thermocouples used for applications including different laboratory environments. The operating temperature range of Type T thermocouples is extensive and hence it was a preferred choice for temperature data acquisition [31].

4.2.1 Thermocouples Set-Up and DAQ Programming

It has been mentioned in Chapter 2 that data was acquired using LabVIEW. LabVIEW DAQs had already been programmed by previous research students when the HXTP was first set-up, but it has only been limited to measuring the water temperature at the inlets and outlets of DWHR systems by the immersion RTDs.

An additional DAQ chassis NI 9213 from National Instruments [32] was available and used as a source of voltage input to the LabVIEW DAQ from the thermocouple junctions. The number of thermocouples that were used was limited to 12 because of chassis capacity. Once soldered thermocouples junctions and labelling was completed, the inputs were extended and fed into the chassis.

The DAQ chassis was programmed in LabVIEW in order to acquire temperature readings at different point locations across DWHR system length. Programming data inputs and outputs in LabVIEW was relatively straightforward and mostly required forming connections of different components.

LabVIEW is a visual programming language. The DAQ chassis is configured with LabVIEW and then used for any required data acquisition. Variables T_1 to T_{12} were created to capture temperature readings for every thermocouple. Once the temperature signals were acquired by the DAQ assistant and retained in the data collector, they were then stored in 12 different arrays each corresponding to different thermocouples. The stored temperature readings were then written to a comma separated value (CSV) file which could be analyzed as required. All of the

data was collected at 1 second intervals which is the same as the main LabVIEW program, which has been used to acquire RTD readings. Moreover, standard date and time were stored for readings at each instant.

The programming page and user interface are interconnected. The user interface image appears for any input/output component variables created on programming page. Figure 4-1 and Figure 4-2 shows the programming page and the user interface respectively. In order to acquire the temperature readings, the play button on Figure 4-2 had to be pressed once. Time counter would start under the “Time Elapsed” and temperature readings would display and change every second. The temperature was recorded in the units of $^{\circ}\text{C}$. The “Stop” button could be pressed to terminate thermocouple temperature acquisition.

Even though the temperature readings by Type T thermocouples are reasonably accurate, calibration was still a crucial step that had to be performed before using thermocouples. All four RTDs on the HXTP had already been calibrated for research purposes. RTDs were used as a reference point to calibrate all 12 thermocouples. Calibration and verification of all the thermocouples are shown in Appendix D.

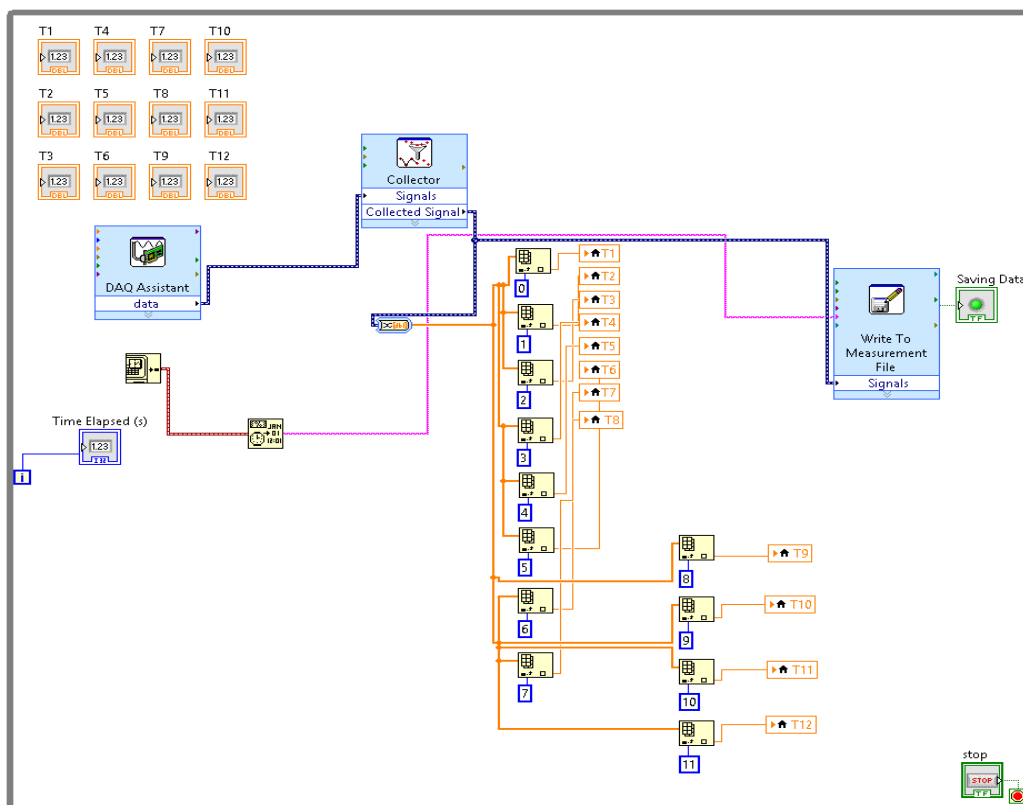


Figure 4-1: Data acquisition program for thermocouples

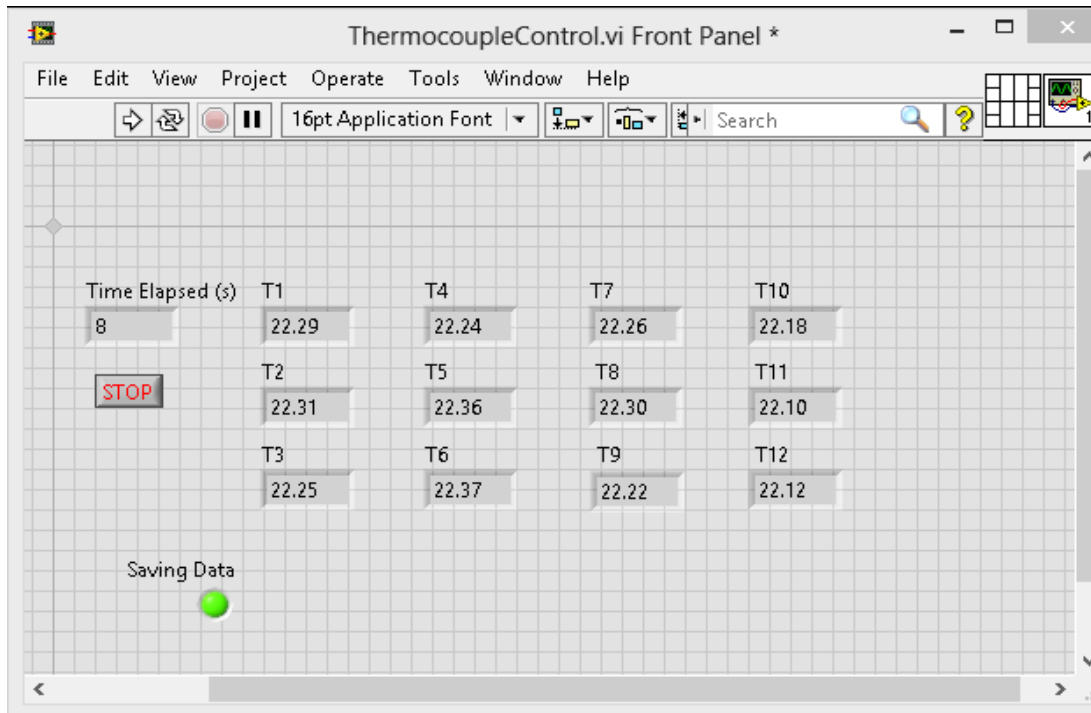


Figure 4-2: User interface of thermocouple inputs and readings

4.2.2 Thermocouple Placement Plan and Potential Issues

A thermocouple was placed on the mains-side inlet and outlet to ensure meaningful temperature readings. It was expected that the readings of thermocouples at entry and exit would be very close to what was reported by the immersion RTDs. Hence, this placement at inlet and outlet was also a check on the validity of temperature outputs of the thermocouples. The remaining eight thermocouples were evenly spaced across the mains-side coils.

The coils of all DWHR systems used in this experimental study were divided into sets of 4 as shown in Figure 4-3. This is how most of the DWHR systems are manufactured by RenewABILITY Energy Inc. Each set of 4 coils was called a “coil set” in this thesis.



Figure 4-3: Coil set of 4 coils on a random DWHR system

Even though it had been well established that the thermocouples would provide very accurate readings, there was one problem with using them. The smallest DWHR system available in STRL was 36" long drain-side and had 14 coil sets. Dividing 8 thermocouples over 14 coil sets would not be the best idea as a lot of information regarding temperature change would not be captured. Moreover, thermocouples are only able to provide measurements at a single point. This is another reason why it was decided to use a thermal camera. As was stated previously, the thermal imaging camera allows the analysis of the entire surface, with temperature validation at the thermocouple measurement points.

4.3 Thermography Camera Set-up and Finalized Equipment Selection

Thermal imaging cameras are a powerful tool which can provide a lot of detailed information regarding temperature change on the targeted surface. They detect and convert infrared energy (heat) into electronic signals, which can then be processed to produce thermal images. Very detailed temperature pattern arrays known as thermograms can then be generated [20]. The processed thermal image can be broken down into temperature measurements across the entire thermal imaging frame [33]. The key benefit of using thermal imaging camera is its ability to generate thermograms for the entire DWHR system surface. More information on how data from the thermal camera was analyzed is shown in upcoming sections.

4.3.1 Thermal Camera Description and Benefits

A FLIR T-400 series camera was used for this analysis. This research grade camera had the thermal sensitivity of 0.05°C . It was 320 columns x 240 rows pixel IR with a frame rate of 6 Hz [34]. The camera had 3.1 mega pixel of clarity and could simultaneously capture thermal and visible images.

One benefit of using the FLIR T-400 was its compatibility with the ResearchIR software [35]. It was able to output a 320 x 240 CSV file per frame showing temperature for each pixel, and a thermal image for each single frame, at the rate of about 6 frames per second. For example, if a test was run for 50 seconds, ResearchIR would generate approximately 300 CSV files and infrared images which could be processed as needed. Lot of temperature data availability was another major benefit of using the thermal camera. Hence, the thermal camera would provide more than enough data which would have to be processed to derive any useful results.

The use of a thermal camera could only be justified if the temperature readings were similar to that of thermocouples. Hence, the proposed plan was to run both the thermocouples and camera together on selected DWHR systems to ensure that temperature readings agreed for both. If it could be proved that both the measuring devices showed very similar temperature readings, data given by the camera would most likely be used for any location of the DWHR system. It would help to get rid of point measurement constraint posed by the thermocouples.

4.3.2 Surface Conditioning Approximations

Thermal cameras work by capturing infrared light emitted, reflected and transmitted by the objects in view of the camera lens [36]. There is no transmission since DWHR systems are made up of copper. Higher emissivity of the system surface would therefore result in higher amount of infrared light collected by the camera. This would lead to more precise infrared images and thermograms.

Good thermal conductive properties of copper is one major reason why it is used in the manufacturing of DWHR systems. It also has high reflectivity and very low emissivity. The radiative properties of any material is defined by Equation 4.1 [37]:

$$\rho + \alpha + \tau = 1 \quad (4.1)$$

Where ρ , α and τ are reflectivity, absorptivity and transmissivity of the material being used. Due to no transmissivity, Equation 4.1 was reduced to Equation 4.2 as follows:

$$\rho + \alpha = 1 \quad (4.2)$$

It was assumed that copper was at thermodynamic equilibrium in order to simplify the problem. The assumption of grey body which allowed to establish constant emissivity over all wavelengths, simplified the use of Kirchhoff's law of thermal radiation which states that emissivity is equal to absorptivity [38]. Therefore α in Equation 4.2 was substituted with emissivity ε . The final result is shown in Equation 4.3 which was used to experimentally estimate the emissivity of copper.

$$\rho + \varepsilon = 1 \quad (4.3)$$

The emissivity of copper was estimated using a Gier Dunkle DB-100. The DB-100 is an infrared reflectometer which measures infrared reflectance of any sample [39]. Once reflectance is measured, emissivity of a sample is estimated using Equation 4.3.

In order to measure reflectance of copper, a flat square copper plate of dimensions 4"x4" was cut out and measurements were made evenly throughout the entire surface. Figure 4-4 shows the approximate reflectivity measurement locations on the flat copper plate.

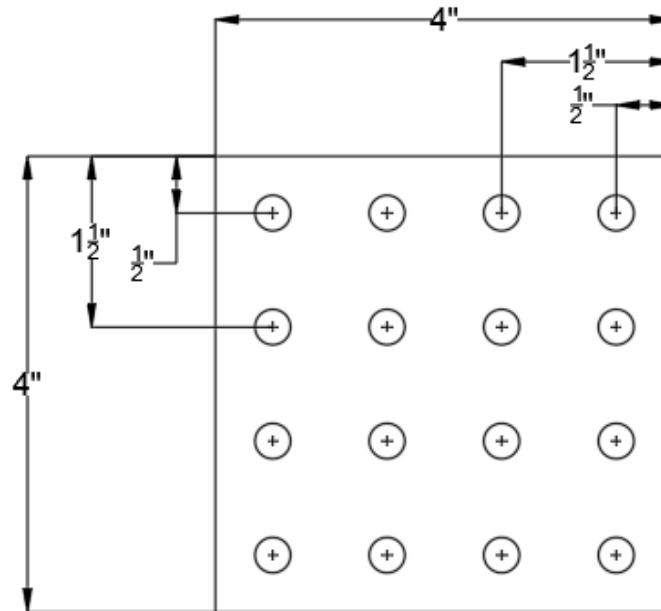


Figure 4-4: Approximate reflectivity measurement locations on flat copper plate (Not to Scale)

The average reflectivity and emissivity of copper plate were determined to be 0.935 and 0.065 respectively. This meant that very little infrared radiation would be captured by the thermal camera lens, if the DWHR systems were used as they were. Hence, the thermograms obtained would not be very accurate.

The copper surface is very reflective, and this is not good for infrared thermography. The DWHR systems therefore were painted flat black. A black surface would be a better emitter of radiation [40].

Initially, a single coat of spray paint was applied but it didn't completely cover the surface of the copper plate since some spots were visible. Hence, another coat was applied to ensure no surface exposure of copper. The applied double layer of spray paint was very thin and wouldn't significantly impact the infrared heat coming off the DWHR systems. Table 4-1 shows the estimated emissivity at different spots of the copper plate with no layer, single layer and double layer of black stove paint.

Table 4-1: Emissivity of copper plate with no, single and double coat of black paint

	Emissivity ϵ			
Copper Surface	0.069	0.068	0.055	0.062
	0.071	0.062	0.040	0.052
	0.063	0.067	0.050	0.103
	0.050	0.061	0.073	0.094
Single coat	0.872	0.861	0.846	0.862
	0.840	0.832	0.856	0.853
	0.863	0.872	0.841	0.854
	0.818	0.851	0.866	0.856
Double coat	0.870	0.866	0.856	0.873
	0.853	0.862	0.860	0.864
	0.868	0.871	0.858	0.854
	0.845	0.865	0.868	0.859

The average emissivity values of single coat and double coat were estimated to be 0.853 and 0.862 respectively. This led to a conclusion of applying a double coat of black stove paint to the selected DWHR systems before performing infrared thermography. It would significantly enhance the emissivity of infrared radiation from the DWHR system surface.

4.3.3 Selection of DWHR systems for Infrared Thermography

It was expected that post processing would take a long time to derive any useful results due to the abundance of data collected by the thermal camera as mentioned in Section 4.3.1. Therefore, it was desirable to select a small set of DWHR systems. A sample size of 3 DWHR systems were selected. R3-36, R3-60 and R4-36 were the DWHR systems chosen because it gave degrees of freedom for both drain-side diameter and length. Another reason for a smaller sample selection was the limited availability of the thermal camera.

R3-36 and R4-36 had 14 coil sets and a total of 56 coils, while the R3-60 had 24 coil sets and a total of 96 coils. The coil sets were numbered in ascending order from the bottom of the drain-side pipe at mains-side water inlet to the top at mains-side water outlet. For the purpose of this research work, coil set 1 was referred to as “entry coil set”, whereas coil set 14 or 24 depending on the DWHR system was referred to as “exit coil set”.

Figure 4-5 shows the painted DWHR systems used for infrared thermography. A total of 18 tests were to be completed for the entire infrared thermography analysis. Fixed temperatures

of 10°C and 38°C as mentioned in Chapter 2, were used for the mains and drain-side inlets. All tests were run at equal-flow conditions.



Figure 4-5: Double coated DWHR systems used for infrared thermography

4.3.4 Finalized List of Materials

It was determined that a total of 8 essential components were required in order to successfully conduct infrared thermography experiments on DWHR systems. The list of those essential components is as follows:

1. 12 Type T thermocouples.
2. Thermally conductive paste to ensure proper conduction from DWHR system surface to thermocouple junction.
3. Infrared thermography camera.
4. Tripod for mounting and fixing camera location.
5. Thermal insulation to block the exposure of any unwanted drain-side surface to the thermal camera lens. This will be discussed in Section 4.4.1.
6. Black background for blocking any unwanted exposure of surroundings to the camera lens.
7. Selected DWHR systems.
8. Black stove paint to double coat selected DWHR systems.

For the infrared thermography approach, an infrared thermography camera and Type T thermocouples were the key additional pieces of equipment, which were used along with the HXTP. Test method 2 was similar to test method 1, but with the inclusion of thermal camera and thermocouples.

4.4 Test Methodology

4.4.1 Experimental Set-Up

After the DWHR system was placed on the HXTP, thermocouples were attached on its surface. 8 thermocouples were divided evenly across 56 or 96 coils depending on the drain-side length of the DWHR system. Each thermocouple junction was first coated with thermally conductive paste and then placed on the mains-side coils in a way that the junction was always in contact with the surface. The junction was covered with thermally insulating material and duct tape to secure its position. All the thermocouples were attached on the back side of the DWHR systems, such that a complete unobstructed view of the front side was captured by the thermal camera. Figure 4-6 shows the thermocouples attached on the back side of R3-36. This rear view was not captured by the thermal camera.



Figure 4-6: R3-36 with attached thermocouples

In Figure 4-6, it is observed that thermal insulation was applied at the top and bottom of the DWHR system to block any exposure of drain-side pipe to the thermal camera. A problem

with the thermal camera was its inability to fix minimum and maximum temperature scales. The temperature scales would increase if a hotter object came under the scope of camera lens. Since the experiments were focused only on the mains-side coils, any excessive variation in the temperature scales was not desirable.

The next step was to cover the background in black to ensure that the camera didn't capture background radiation sources. Figure 4-7 shows the set-up of R3-36 with thermocouples and black opaque background. A square mark was placed on the first coil of each coil set so that they could be easily differentiated.



Figure 4-7: R3-36 with thermocouples and opaque black background

Finally, the thermal camera was set-up in front of the DWHR system. A lot of attention was given to make sure the images captured by the camera were not blurry and could provide enough details in the thermograms. For R3-36 and R4-36, the distance between the camera lens and system surface was 2.1m. In case of R3-60, this distance increased to 3.4m to ensure that the entire DWHR system was visible in the frame. Figure 4-8 shows the final set-up of R3-60 with thermocouples, opaque black background and the thermal camera placed on a tripod facing the surface.

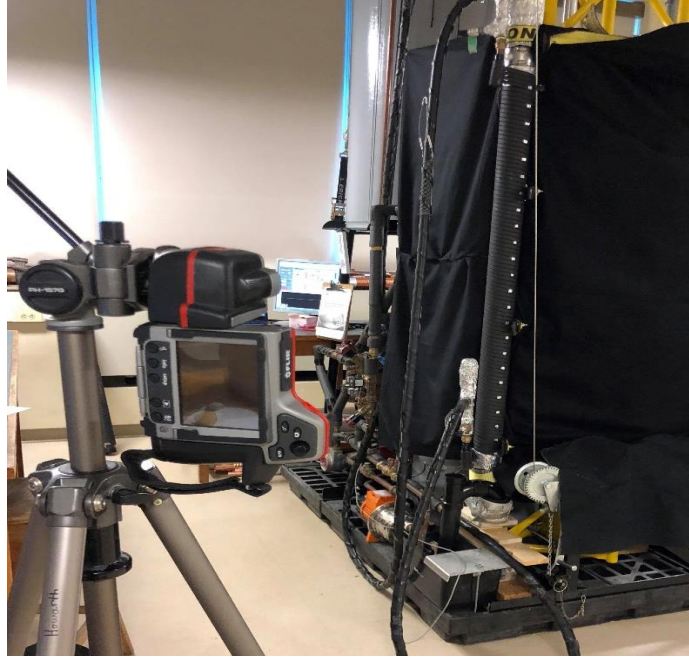


Figure 4-8: R3-60 final set-up with thermocouples, opaque black background and thermal camera

4.4.2 Standard Testing Procedure

After each DWHR system was prepared as per experimental set-up procedure in Section 4.4.1, the last steps needed for accurate temperature data acquisition are as follows:

1. Set emissivity of camera to the estimated value of 0.862 as shown in Section 4.3.2.
2. Place camera at required distance from the surface as mentioned in Section 4.4.1.
3. Calibrate camera date and time with LabVIEW computer to ensure that the RTDs, thermocouples and the thermal camera would acquire temperature readings at the exact same time. This was important to ensure accuracy between measurement timings for all 3 measuring devices.
4. Ensure complete darkness in the lab by lowering all the blinds and turning the lights off. All of the experiments were performed in complete darkness to generate clear and precise thermograms and temperature readings.
5. Start data acquisition for the RTDs, thermocouples and the thermal camera at exactly the same time when the main pump of the HXTP turns on.
6. Acquire data for 4-5 minutes.

4.4.3 Data Storage and Organization

Collected raw data for each test consisted of an excel file each for the RTD and thermocouples which were later combined, a thermal imaging video provided by the camera, a thermal image for each frame, and a CSV temperature file of 320 columns x 240 rows for each frame. Data was collected for about 200 seconds for each test. At the pre-set frame rate of about 6 frames per second, each test provided about 1200 thermal images and CSV files containing temperature readings at each pixel location. All of the raw data including the CSV files is accessible from the STRL at UW. Table 4-2 shows a sample of RTDs and thermocouple raw data collection for one of the tests.

Table 4-2: Raw RTD and thermocouple data sample for R4-36 at 12LPM

Date	GMT -5 hrs	Time (s)	RTD's			THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-12	5:51:19 PM	1	22.36	22.57	11.75	21.83	22.09	22.17	22.32	22.40	22.42	22.46	22.52	22.59	22.38
2018-12-12	5:51:20 PM	2	21.61	22.58	11.8	21.28	21.57	21.68	22.22	22.39	22.44	22.48	22.53	22.62	22.40
2018-12-12	5:51:21 PM	3	20.98	22.59	11.81	20.64	20.92	21.07	21.85	22.29	22.42	22.48	22.53	22.61	22.40
2018-12-12	5:51:22 PM	4	20.28	22.59	11.77	19.96	20.19	20.42	21.36	21.99	22.35	22.50	22.57	22.64	22.42
2018-12-12	5:51:23 PM	5	18.92	22.61	11.8	19.30	19.51	19.77	20.79	21.59	22.16	22.51	22.66	22.73	22.45
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2018-12-12	5:54:37 PM	199	10.14	19.73	12.05	10.12	10.91	12.73	13.67	14.67	17.03	18.76	20.23	21.35	19.64
2018-12-12	5:54:38 PM	200	10.13	19.73	12.08	10.13	10.90	12.72	13.67	14.66	16.99	18.71	20.19	21.34	19.62

Figure 4-9 and Figure 4-10 shows two samples of the thermal images for R4-36 at 12LPM related to time instants shown in Table 4-2. The camera was pitched vertically to capture the entire DWHR system. For all infrared thermography experiments performed in this thesis, the left side of all thermal images represents the bottom cold mains inlet side of DWHR systems.

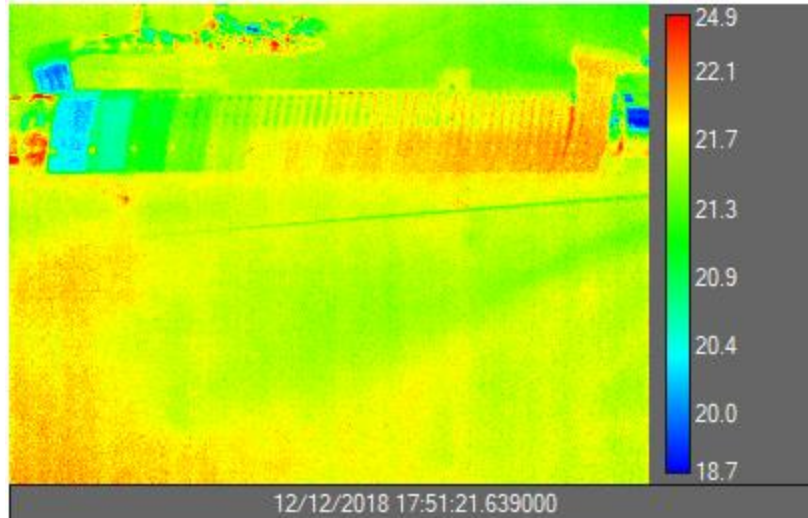


Figure 4-9: Thermal image sample 1 at 12LPM for R4-36 at 3 seconds (°C)

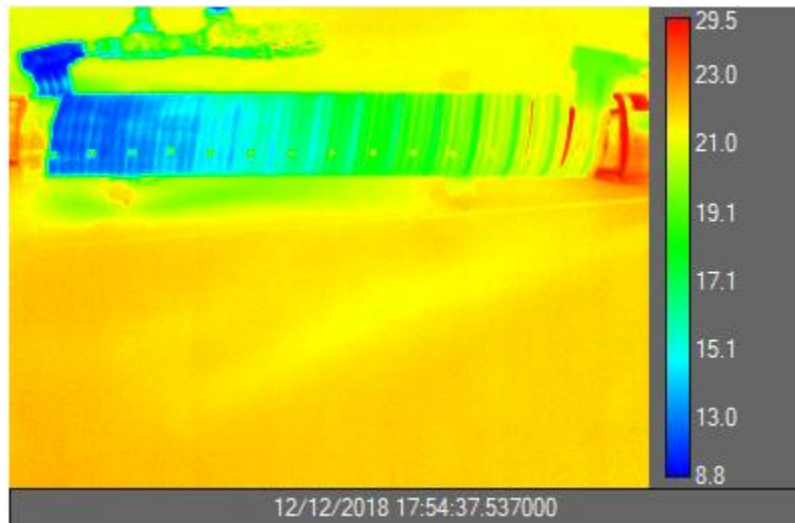


Figure 4-10: Thermal image sample 2 at 12LPM for R4-36 at 200 seconds (°C)

The date and time readings for Figure 4-9 and Figure 4-10 match the time instants in Table 4-2. The camera reads temperature in units of °C. It is important to note that the temperature scale for both figures do not match each other. This is because the camera didn't have a fixed temperature scale. It fluctuated based on the intensity of heat sensation from the DWHR system surface.

Figure 4-9 and Figure 4-10 both show different instances of the same test. Mains-side inlet for all the frames was on the left side. The blue coloured lines indicated that water entered at a lower temperature and heated up as it flowed towards the outlet on right side of the frames. The DWHR system was at ambient room temperature of about $22 \pm 2^{\circ}\text{C}$ at the start as is observed

in Figure 4-9, but as water flow continued, temperature profile changed throughout the entire length. This is evident in Figure 4-10 where the temperature of the DWHR system surface was different at the entry and exit locations. The colour change indicated heating of the surface and water from inlet to outlet.

4.4.4 Time Instants Selection

In transient response experiments, it is extremely challenging to analyze thermal images and CSV files for temperature data extraction at each and every time instant of 1 second. The initial discussion of the transient temperature response of DWHR systems in Chapter 3 shows that most of the change in temperature profiles occurred within the first 50 seconds of the observed DWHR system response. This is the period where temperature readings fluctuated drastically with time. After the initial 50 seconds, the temperature profiles started to reach steady-state and almost negligible change in temperature was observed. Based on that, it was decided to select most of the observational time instants before the first 50 seconds.

Table 4-3 shows the selected time instants for temperature data extraction and analysis. Even though all the raw data is available from STRL, summarized version of raw data for all time instants from all 18 tests is shown in Appendix E.

Table 4-3: Selected time instants for temperature data extraction

Time (seconds)											
1	2	3	5	8	10	15	20	30	50	100	200

Enough temperature data extraction points were selected for the beginning phase of a test in order to capture most of the temperature data in transient part. As time increased, the gap between the selected instants was also increased since less variation in temperature profile was expected.

4.4.5 Surface and Water Temperature Extraction from Raw Data

Extraction of temperature readings from the RTDs and thermocouples was straightforward. For all 18 tests, temperature values were picked up from the raw data at each time instants stated in Table 4-3.

Table 4-4 shows the summarized form of the extracted temperature values in °C for R4-36 at 12LPM at the selected time instants. Columns of the “Thermocouple surface temperature”

section in Table 4-4 were derived from the rows of raw data shown in Table 4-2. Summarized form of the extracted temperature values for all cases are shown in Appendix F.

The distance column in Table 4-4 was non-dimensionalized, since all temperature measuring instruments (RTDs, thermocouples and camera measurements at each coil set) were available in different quantities. Mains-side inlet and outlet were marked 0 and 1 as they represented the entry and exit points of DWHR systems. For thermocouples, all divisions in the middle were derived by dividing the entire non-dimensionalized length by 8. It is important to note that all the thermocouples in the middle were placed at equal distances from each other. Divisions for coil sets were derived by dividing non-dimensionalized length by number of coil sets. For example, non-dimensional distance of 0.07 represents coil set 1 and so on.

Table 4-4: R4-36 mains-side temperature values at 12LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.36	21.61	20.98	18.92	16.60	15.69	14.00	12.57	11.48	10.66	10.26	10.13
	0.07	22.37	21.67	21.09	19.17	17.01	16.17	14.57	13.20	12.12	11.29	10.90	10.77
	0.13	22.39	21.74	21.19	19.41	17.42	16.64	15.15	13.83	12.77	11.92	11.54	11.41
	0.20	22.40	21.80	21.30	19.66	17.83	17.12	15.72	14.46	13.41	12.55	12.18	12.05
	0.27	22.42	21.87	21.41	19.90	18.25	17.60	16.30	15.10	14.05	13.19	12.81	12.69
	0.33	22.43	21.93	21.52	20.15	18.66	18.07	16.87	15.73	14.69	13.82	13.45	13.33
	0.40	22.44	22.00	21.62	20.40	19.07	18.55	17.44	16.36	15.34	14.45	14.09	13.97
	0.47	22.46	22.06	21.73	20.64	19.48	19.03	18.02	16.99	15.98	15.08	14.73	14.61
	0.53	22.47	22.13	21.84	20.89	19.89	19.50	18.59	17.62	16.62	15.71	15.37	15.25
	0.60	22.49	22.19	21.95	21.13	20.30	19.98	19.17	18.25	17.26	16.34	16.01	15.89
	0.67	22.50	22.26	22.05	21.38	20.71	20.46	19.74	18.88	17.91	16.97	16.65	16.53
	0.73	22.51	22.32	22.16	21.63	21.12	20.93	20.31	19.51	18.55	17.60	17.29	17.17
	0.80	22.53	22.39	22.27	21.87	21.54	21.41	20.89	20.15	19.19	18.24	17.92	17.81
	0.87	22.54	22.45	22.38	22.12	21.95	21.89	21.46	20.78	19.83	18.87	18.56	18.45
	0.93	22.56	22.52	22.48	22.36	22.36	22.36	22.04	21.41	20.48	19.50	19.20	19.09
	1.00	22.57	22.58	22.59	22.61	22.77	22.84	22.61	22.04	21.12	20.13	19.84	19.73
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	21.83	21.28	20.64	19.30	17.45	16.37	14.34	13.07	11.75	10.80	10.36	10.13
	0.11	22.09	21.57	20.92	19.51	17.61	16.54	14.63	13.46	12.31	11.53	11.11	10.90
	0.22	22.17	21.68	21.07	19.77	18.12	17.35	15.82	14.91	14.08	13.53	13.06	12.72
	0.33	22.32	22.22	21.85	20.79	19.16	18.37	16.84	15.92	15.06	14.55	14.06	13.67
	0.44	22.40	22.39	22.29	21.59	20.18	19.41	17.92	16.97	16.03	15.51	15.03	14.66
	0.56	22.42	22.44	22.42	22.16	21.38	20.90	19.80	19.08	18.39	17.94	17.51	16.99
	0.67	22.46	22.48	22.48	22.51	22.24	21.99	21.22	20.63	19.99	19.53	19.21	18.71
	0.78	22.52	22.53	22.53	22.66	22.84	22.80	22.37	21.96	21.31	20.85	20.61	20.19
	0.89	22.59	22.62	22.61	22.73	23.05	23.15	23.13	22.85	22.19	21.69	21.47	21.34
	1.00	22.38	22.40	22.40	22.45	22.64	22.63	22.27	21.75	20.83	20.01	19.80	19.62
COILSET SURFACE TEMPERATURE (°C)	0.00	22.36	21.61	20.98	18.92	16.60	15.69	14.00	12.57	11.48	10.66	10.26	10.13
	0.07	21.44	20.95	20.33	18.99	17.29	16.42	15.01	14.01	13.03	12.38	12.17	12.02
	0.13	21.56	21.24	20.67	19.34	17.55	16.64	15.21	14.16	13.11	12.42	12.25	12.12
	0.20	21.62	21.50	21.09	19.91	18.25	17.37	16.03	15.03	13.99	13.36	13.20	13.05
	0.27	21.64	21.64	21.37	20.32	18.72	17.83	16.53	15.53	14.46	13.79	13.63	13.55
	0.33	21.62	21.63	21.54	20.70	19.21	18.38	17.12	16.15	15.09	14.42	14.25	14.17
	0.40	21.65	21.67	21.67	21.12	19.86	19.11	17.98	17.06	16.01	15.37	15.21	15.08
	0.47	21.67	21.70	21.74	21.43	20.40	19.71	18.68	17.79	16.73	16.09	15.93	15.82
	0.53	21.69	21.73	21.78	21.70	20.95	20.38	19.50	18.67	17.62	16.98	16.88	16.75
	0.60	21.72	21.76	21.82	21.87	21.39	20.91	20.18	19.41	18.40	17.79	17.69	17.58
	0.67	21.72	21.76	21.83	21.95	21.76	21.41	20.84	20.16	19.21	18.64	18.59	18.47
	0.73	21.73	21.76	21.84	21.98	22.05	21.81	21.42	20.82	19.92	19.38	19.35	19.26
	0.80	21.75	21.80	21.87	22.06	22.38	22.27	22.03	21.49	20.62	20.11	20.07	19.92
	0.87	21.80	21.85	21.92	22.10	22.59	22.62	22.54	22.05	21.20	20.69	20.66	20.51
	0.93	21.81	21.87	21.94	22.08	22.70	22.86	22.98	22.57	21.81	21.30	21.28	21.16
	1.00	22.57	22.58	22.59	22.61	22.77	22.84	22.61	22.04	21.12	20.13	19.84	19.73

Deriving surface temperatures at the coil sets from the CSV files was more challenging than for the RTDs and thermocouples. Since the ResearchIR software gave locations for each pixel on the frames, temperatures for the entire surface of the DWHR system facing the camera were known. Even on the coil set surface, temperature readings were not constant. There were slight variations in temperature for the entire coil sets. In order to simplify this problem of more data, an average of temperature readings for each coil set was taken in the middle of the DWHR system by assuming a uniform surface temperature. This assumption of a uniform surface temperature is validated in Section 4.4.6. Figure 4-11 shows a schematic of the camera frame, and approximate coil set temperature measurement locations in the middle of the DWHR system.

Since the camera had a frame rate of 6 frames per second, average of temperature pixels in the centreline of DWHR system were taken throughout all 6 frames for each coil set. The dark lines on Figure 4-11 shows the approximate locations of targeted pixels for each test. A script was programmed in MATLAB in order to streamline the process of estimating temperature in the middle. The inputs for the script were frame numbers and coil set pixel locations for each time instant. Appendix G shows the script used for temperature extraction from camera CSV files. All of the averaged surface temperature readings are represented in the “Coil set surface temperature” rows of Table 4-4.

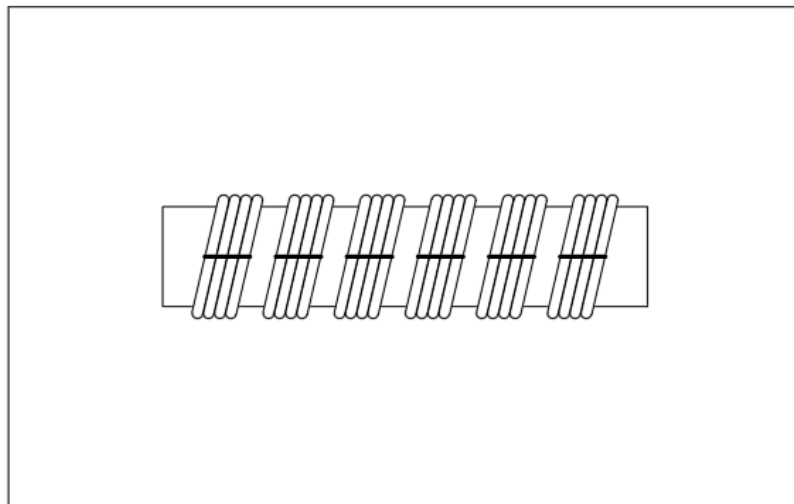


Figure 4-11: Schematic of pixel selection for coil set temperature determination

4.4.6 Isothermal Surface Temperature Validation at Coil Sets

The assumption of uniform surface temperature across each coil set made in Section 4.4.5, was validated using the principle of lumped capacitance method. It enabled the assumption of a solid surface to have a spatially uniform temperature and negligible temperature gradients [41]. The critical parameter for lumped capacitance is Biot number (Bi) which is the ratio of surface convection to internal conduction over the solid body of interest and can be estimated by Equation 4.4 as:

$$Bi = \frac{hL_c}{k} \quad (4.4)$$

This equation was applied on each coil set for all time instants and tests to justify the use of a single averaged surface temperature point. In the above equation, h represented the convection coefficient of water flowing through each coil set, which was calculated based on the estimated water temperature and flowrate. k_{solid} is the thermal conductivity of copper which was assumed to be constant at 401 W/mK. The last variable was characteristic length which represented the ratio of volume to surface area of coils.

If $Bi \ll 1$, the temperature gradients within the solid were small and the assumption of uniform surface temperature would be reasonable [41]. Hence, the first step performed was to calculate Bi for all the tests and time instants at each coil set. The only 2 parameters that were needed to be calculated in Equation 4.4 were L_c and h which are shown below.

It is important to note that the calculations of any parameters like h , Bi, d_h etc. were performed on each coil and not the coil set. This was the case because it was much easier to determine the internal dimensions of the coils rather than coil sets. Hence, all the parameters calculated in Section 4.4.6 will be based on coil basis.

4.4.6.1 Estimation of Characteristic Length and Hydraulic Diameter of Rectangular Helical Coils

There are a limited number of convection correlations when it comes to the flow in helical coils. More specifically, the correlations that are available apply only to circular helical coils. Hence, in order to be able to apply any correlations to the rectangular helical coils, the most important parameter needed was the hydraulic diameter d_h . The overall cross-sectional schematic of any DWHR system and coil dimensions are shown in Figure 4-12 and Figure 4-13. All dimensional data for the 3 DWHR systems used in this experiment and the calculated d_h are

shown in Table 4-5. The parameter d_h was calculated only for R4-36 for demonstration purposes and is shown below.

$$a = a_o - [2(\text{wall thickness})] = 4.9\text{mm}$$

$$b = b_o - [2(\text{wall thickness})] = 9.67\text{mm}$$

$$d_h = \frac{4A_c}{P}$$

$$= \frac{(4ab)}{2(a + b)} = 6.50\text{mm}$$

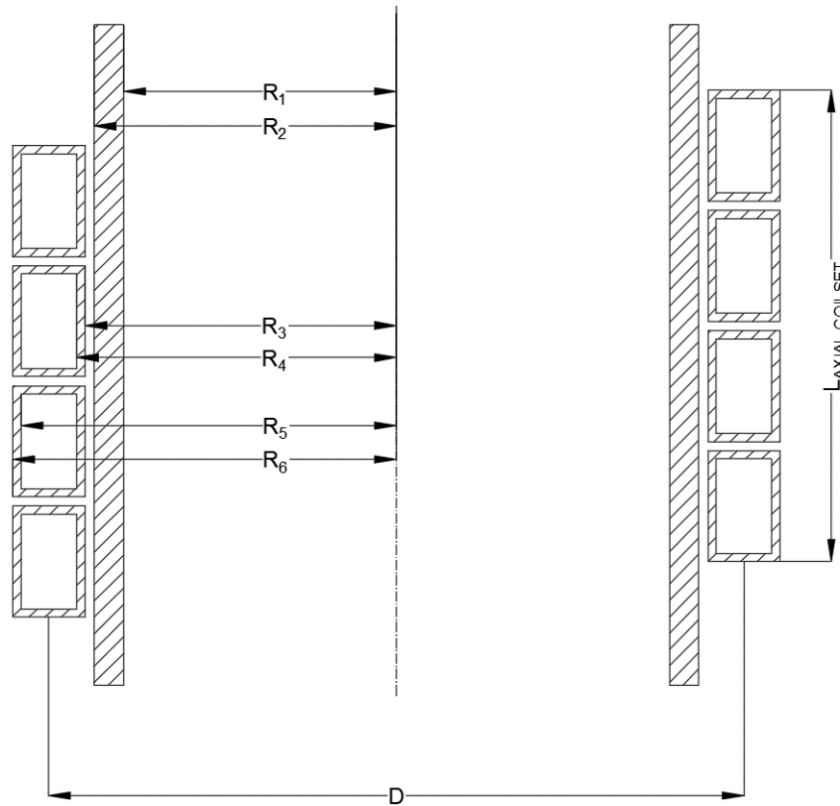


Figure 4-12: Cross-sectional schematic of DWHR system

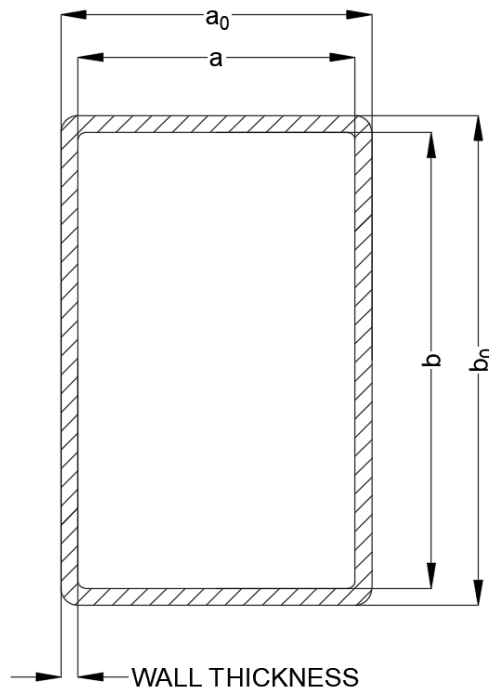


Figure 4-13: Mains-side coils dimensions schematic

Table 4-5: Key dimensions of DWHR systems and mains-side coils

	R 3-36	R 3-60	R 4-36
R1 (mm)	38.66	38.17	50.30
R2 (mm)	39.49	39.67	52.64
R3 (mm)	39.54	39.72	52.69
R4 (mm)	41.06	41.24	54.21
R5 (mm)	44.10	44.47	58.70
R6 (mm)	45.62	45.99	60.22
L _{axial Coilset} (mm)	57.61	57.61	55.80
L _{coil circumference} (mm)	284.00	284.00	344.00
a ₀ (mm)	7.23	7.23	7.94
b ₀ (mm)	13.43	13.43	12.71
Wall thickness (mm)	1.52	1.52	1.52
a (mm)	4.19	4.19	4.90
b (mm)	10.39	10.39	9.67
D (mm)	84.01	84.76	112.50
d _h (mm)	5.97	5.97	6.50

4.4.6.2 Estimation of Laminar Convection Coefficients and Biot Number

It was unknown whether the water flow in the mains-side coils was laminar or turbulent. Hence, 2 different h values named as h_{laminar} and $h_{\text{turbulent}}$ were calculated using the convection correlations for both laminar and turbulent flow. Only a single sample calculation is presented for h_{laminar} and $h_{\text{turbulent}}$ for R4-36 at the flowrate of 12LPM during the 200 second time instant on the 4th coil set. Coil set 4 had non dimensionalized length of 0.27 when cross referenced with Table 4-4. This was called as the “sample calculation scenario” and was also used in the energy balance section of this thesis.

The laminar convection coefficient for the specified coil set was estimated using the correlation provided by Manlapaz and Churchill [42] which shows that:

$$h_{\text{laminar}} = (0.913) \left(\frac{k_{\text{water}}}{d_h} \right) (De^{0.476}) (Pr^{0.2}) \quad (4.5)$$

Where De is the Dean's number which gives information about the secondary fluid motion in curved pipes and is estimated as [43]:

$$De = Re_D \sqrt{\frac{d_h}{D}} \quad (4.6)$$

Re_D represents the Reynolds number of water flow in the coils and is calculated as [44]:

$$Re_D = \frac{\rho V d_h}{\mu} \quad (4.7)$$

Where V is the velocity of water in the coils. Since all the properties were being evaluated at the coils, the flowrate was divided by 4 before it was converted into fluid velocity. Substituting Equation 4.6 and 4.7 into Equation 4.5 yielded the final expression that was evaluated for estimating h_{laminar} .

$$h_{\text{laminar}} = [0.913] \left[\frac{k_{\text{water}}}{d_h} \right] \left[\left(\frac{\rho V d_h}{\mu} \right) \left(\sqrt{\frac{d_h}{D}} \right) \right]^{0.476} [Pr^{0.2}] \quad (4.8)$$

All of the variables in Equation 4.8, except d_h and D represented water properties at a certain fixed temperature. From Table 4-4, it was observed that for the calculation parameters shown above, T_{water} was estimated to be about 12.69°C or 285.84K, at non-dimensionalized coil set distance of 0.27. All of the water properties were linearly interpolated at the specified temperature from the heat transfer textbook [28] and are summarized in Table 4-6.

Table 4-6: Water properties for sample calculation scenario

Water properties	
ρ (kg/m ³)	999.83
C_p (kJ/kgK)	4.1882
μ (Ns/m ²)	0.0012
k (W/mK)	0.5913
Pr	8.6000

The only remaining parameter that had to be evaluated was the fluid velocity V in the coils. Summarized raw data in Table 4-2 at the selected time instants for the sample calculation scenario showed that the CSA flowrate across the DWHR system at 200 seconds was 12.08LPM. Since everything related to the convection coefficients was being calculated on a coil basis, the volumetric flowrate was divided by 4 assuming that the flowrate was equal in all coils of the coil sets. Hence, the volumetric flowrate per coil was about 3.02LPM. This was converted into fluid velocity and then used for estimating h_{laminar} as shown below. It is important to note that “ ab ” represented the cross-sectional area of the rectangular coils in m².

$$V = \left(3.02 \frac{\text{L}}{\text{min}}\right) \left(\frac{1 \text{ min}}{60 \text{ s}}\right) \left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right) \left(\frac{1}{ab}\right) = 1.062 \frac{\text{m}}{\text{s}}$$

All of the estimated parameters were finally substituted into Equation 4.8, which yielded h_{laminar} for this specific case to be 3992.28 W/m²K. This calculated h_{laminar} was substituted into Equation 4.9 to estimate Bi_{laminar} .

$$Bi_{\text{laminar}} = \frac{h_{\text{laminar}} L_c}{k_{\text{copper}}} \quad (4.9)$$

It is important to note that the calculated h value would be constant through each coil of the specific coil set. The last unknown parameter to calculate Biot number was the characteristic length L_c , which is the ratio of volume to surface area of the solid body of interest [41]. Since the dimensions of DWHR systems were already known from Table 4-5, the volume and surface area were easily calculated at per coil basis and converted to L_c .

$$L_c = \frac{\text{Vol}}{\text{Surface Area}} = \frac{ab L_{\text{coil circumference}}}{(\text{Perimeter}_{\text{coil}})(L_{\text{coil circumference}})} = \frac{ab L_{\text{coil circumference}}}{2(a + b) L_{\text{coil circumference}}}$$

$$L_c = \frac{ab}{2(a + b)} = 0.001626 \text{ m}$$

At this point, all the known parameters were plugged into Equation 4.9 in order to determine $Bi_{laminar}$ which is estimated as follows:

$$Bi_{laminar} = \frac{(3992.28)(0.001626)}{(401)} = 0.01619$$

Since $0.01619 \ll 1$, the approximation of uniform surface temperature could be assumed for this case. $Bi_{laminar}$ for all the tests was found to be significantly less than 1 which suggested that the approximation of uniform surface temperature was valid. The laminar convective heat transfer coefficients and Biot number values for all coil sets are shown in the next section. It is important to note that the calculated values for laminar case shown in Section 4.4.6.2 might be slightly different from the ones shown in Table 4-7 due to rounding errors. Very similar approach was used for the turbulent case which is shown in the next section. Both laminar and turbulent calculations for the sample calculation scenario are tabulated together in the next section.

4.4.6.3 Estimation of Turbulent Convection Coefficients and Biot Number

The correlation used to estimate $h_{turbulent}$ was provided by Rogers and Mayhew and is shown in Equation 4.10 [45]. Same time instants and fluid properties were used as for the laminar section. The only difference is the actual correlation itself.

$$h_{turbulent} = [0.023] \left[\frac{k_{water}}{d_h} \right] \left[\frac{\rho V d_h}{\mu} \right]^{0.8} [Pr^{0.4}] \left[1 + 3.4 \left(\frac{d_h}{D} \right) \right] \quad (4.10)$$

Evaluation of all the variables yielded $h_{turbulent}$ to be 6027.55 W/m²K. Moreover, $Bi_{turbulent}$ was found using Equation 4.9 by using $h_{turbulent}$ instead of $h_{laminar}$. $Bi_{turbulent}$ was evaluated as 0.02444 which was significantly smaller than 1. Since all of the estimated laminar and turbulent Biot numbers were significantly smaller than 1, it was safe to assume isothermal surface temperature for coil sets for all the experiments. Table 4-7 shows the calculated laminar and turbulent convective heat transfer coefficients and Biot numbers of all coil sets in the sample calculation scenario.

Table 4-7: Heat transfer coefficients and Biot number approximations at sample calculation scenario

Coilset	h_{lam} (W/m²K)	Bi_{lam}	h_{turb} (W/m²K)	Bi_{turb}
1	3916	0.0159	5879	0.0238
2	3944	0.0160	5935	0.0241
3	3970	0.0161	5987	0.0243
4	3991	0.0162	6027	0.0244
5	4013	0.0163	6066	0.0246
6	4034	0.0164	6107	0.0248
7	4056	0.0164	6148	0.0249
8	4078	0.0165	6189	0.0251
9	4101	0.0166	6231	0.0253
10	4124	0.0167	6274	0.0254
11	4146	0.0168	6317	0.0256
12	4168	0.0169	6360	0.0258
13	4191	0.0170	6403	0.0260
14	4214	0.0171	6448	0.0261

The MATLAB script used to interpolate water properties and calculate h and Bi for both the laminar and turbulent cases is shown in Appendix K.

Chapter 5 Analysis, Results and Discussions for Test Method 2

5.1 Results Declaration for Test Method 2

One of the most important points to be stated before data analysis is that since similar trends were observed for all experiments, all of the sample plots and tables shown in this chapter are representative of the entire data set. Only a single case of tables and plots were presented in this chapter. The remaining tables, plots and extra reference materials for all test cases can be accessed from the Appendix section of this thesis.

Unlike test method 1 where the energy balance was applied to the entire DWHR system, in this case energy balance calculations were performed individually on each coil set before adding the results.

5.2 Results for Test Method 2

5.2.1 Temperature Profile Plots across DWHR System Length at different Time Instants

The temperature plots for R4-36 at 12LPM will be shown in this section. The plots shown in this section serve the sole purpose of commenting on temperature profile observed across the DWHR system length for all 3 systems. These plots are relevant to the temperature data shown in Table 4-2 and Table 4-4. The plots of other cases are shown in Appendix I.

Figure 5-1 shows the temperature profile plots for R4-36 at 12LPM for selected time intervals. It shows the temperature readings from RTDs, thermocouples and camera at different time instants. The only true readings for water temperature were given by the RTDs. Both the thermocouples and infrared camera read the DWHR system surface temperature. Hence, the key purpose of this exercise was to understand how the mains water temperature changed across the DWHR system length, as it travelled through the mains-side coils.

It was observed that the temperature profiles started almost as flat horizontal lines at the start of the test, since water in the coil sets and the surface were at constant ambient temperature conditions. As the test proceeded, the water temperature at the mains-side inlet started to drop as the mains water entered the coils. This is evident from the vertical drop in Figure 5-1 at the non-dimensionalized length of 0 on the inlet side of DWHR system. Moreover,

as the drain water reached the mains inlet side of the DWHR system, it had already lost most of its thermal energy and hence didn't provide enough heating to the mains water.

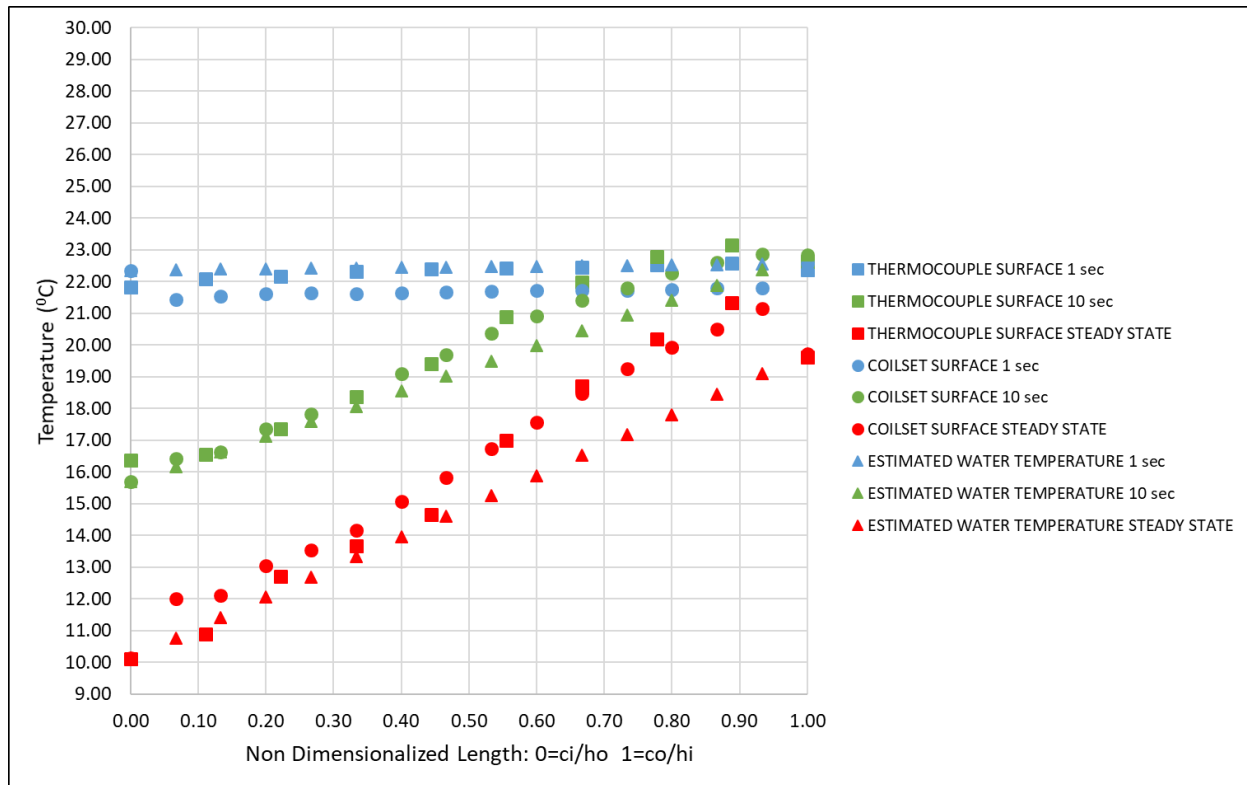


Figure 5-1: Mains-side temperature profiles at different time instants for R4-36 at 12LPM

The water temperature at the mains-side outlet didn't drop as much as the inlet side. Since the hot drain water entered the drain-side inlet of the DWHR system near the mains-side outlet and supplied most heat in that zone, the drop was much smaller on the mains-side outlet water temperature (T_{co}).

It is also evident from Figure 5-1 that both thermocouples and camera temperature readings (circular markers) were very similar near the inlet and outlet points. The temperature profile finally took a positive slope across the non-dimensionalized length indicating heating of the DWHR system from mains inlet to mains outlet side. The surface temperature readings given by the thermocouples and the camera were relatively similar and mostly followed the same pattern.

A linear increase in the surface temperature was observed to the end of DWHR system length where it dropped to the actual water temperature. This linear increase in the coil set surface temperature suggested that the mains water inside the coil sets gained heat in the same

pattern as well. The camera was giving a higher temperature reading due to the effects of conduction in copper coil sets. Since the RTDs were the only source of water temperature and the nature of increase of coil set surface temperature was determined to be linear, it was assumed that the water temperature throughout the DWHR system across all coil sets would also increase linearly. Hence, a straight line was drawn between the RTD inlet and outlet temperatures for each time instant of all 18 tests that were conducted. Water temperatures across each coil set were estimated from the assumed linear behaviour. Figure 5-1 also shows the estimated water temperatures across each coil sets marked with a triangular marker. “Estimated water temperature” section of Table 4-4 shows the approximated readings for water temperature inside the coil sets.

The drop in the surface temperature at the end of the coils was due to the impact of warmer drain-side pipe. Heat conduction from the drain-side pipe to the coils induced a higher temperature reading. This is evident from the cold mains outlet section in Figure 4-10. Surface temperature of the coils were higher just before they lost contact with drain-side pipe. After the contact was lost, the surface temperature dropped near-to the actual water temperature because of negligible conduction from the drain-side pipe to the water coils. The bumps near the ends in Figure 5-1 for 200 seconds time instant is a good indication of surface temperatures falling near water temperatures after the drain-side pipe contact is lost.

Table 4-4 was also used to determine the surface and water temperature change across each coil set throughout the test duration which is shown in Figure 5-2 and Figure 5-3 for the case of R4-36 at 12LPM. All other plots are shown in Appendix J.

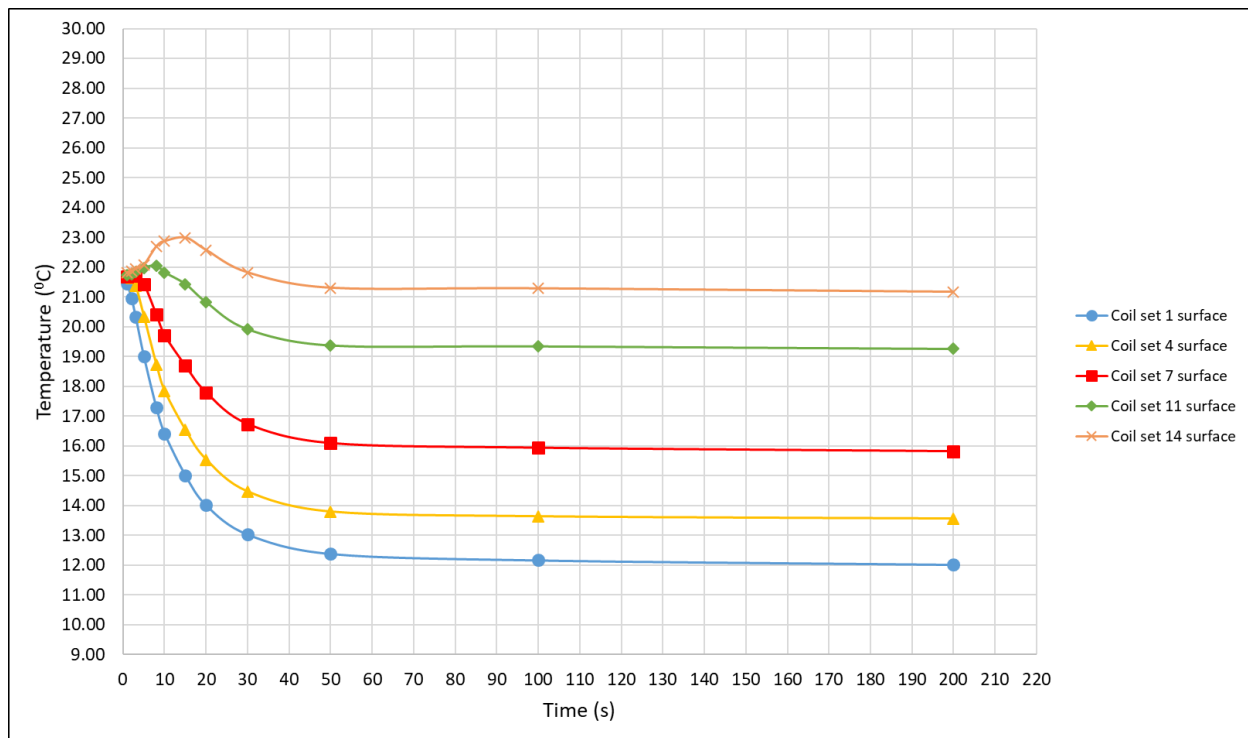


Figure 5-2: Coil set surface temperature profiles at different time instants for R4-36 12LPM

Based on Figure 5-2, the coil sets were almost isothermal at the start of the test since the temperature profiles diverge from a single temperature point. Coil set 1 was closest to the mains inlet. The coil set number increased as water approached the mains-side outlet, thus making coil set 14 just before the exit from the mains-side.

Figure 5-2 shows that the entry coil sets registered the maximum change in surface temperature as was observed from the temperature drop. The change in surface temperature decreased as the mains water travelled through the coil sets. This was an indication that the drain water had the least impact at the bottom of the DWHR system, where the surface temperature was the coldest. Hence, the warmer the drain water was, the more impact it would have on the coil surface.

The bumps at the beginning phase of the test were due to the introduction of warmer gray water in the drain-side pipe which resulted in a sharp increase in surface temperature. As the mains water started to flow in the coils, the surface temperature also began to drop and the bump was diminished. The bumps were visible more on the coils which were located towards the mains-side outlet (higher coil set numbers) as it was the zone where drain water was the hottest.

As stated before, the linear increase in the coil set temperatures have suggested that mains water temperature may also have gained thermal energy in the similar manner. It was assumed that the measured linear like surface temperature profile of the coil sets was the offset of water profile in the respective coil sets. Even though this discussion section is focused mainly on the coil set surface temperatures, the reasoning provided could be applied to water in the respective coil sets. Figure 5-3 shows the estimated water temperature profile in the coil sets based on the linear assumption. Comparing to Figure 5-2, it was observed that the water temperature profiles behaved in the same way as the coil set surface temperature profiles. It was observed that the water temperature was slightly lower in each coil set when compared to the surface temperature for the specific coil set, which stated that mains water was getting heated as it flowed upwards toward the mains-side outlet.

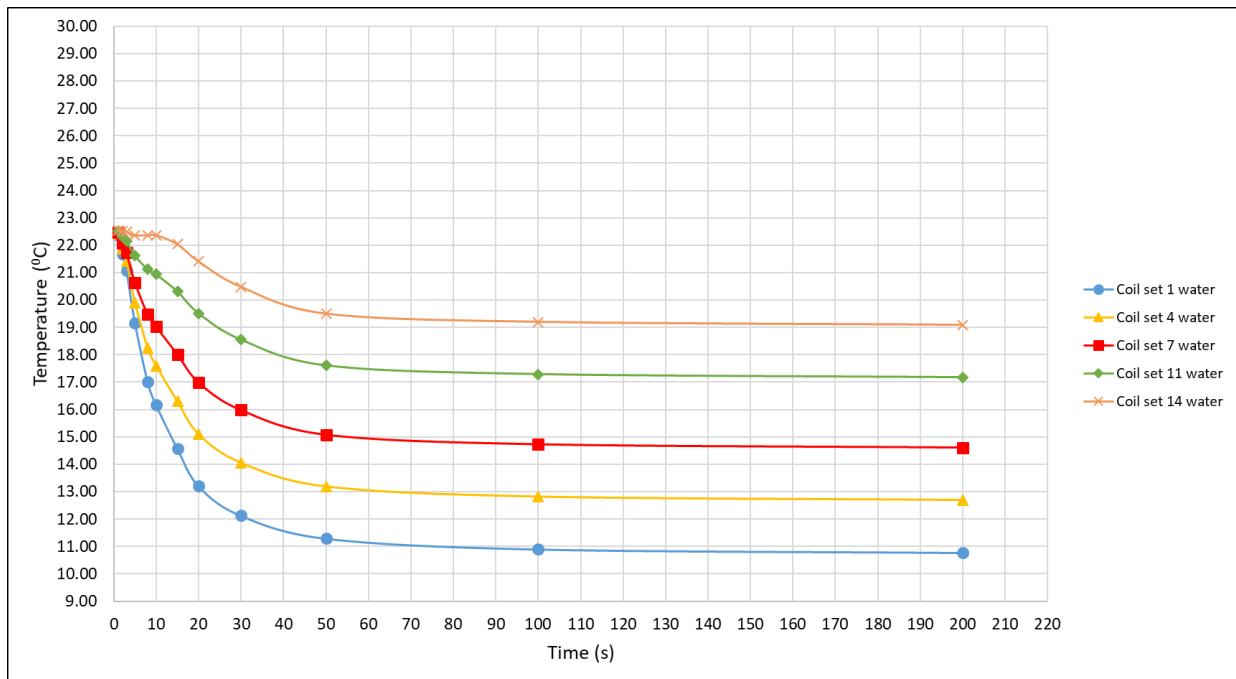


Figure 5-3: Estimated coil set water temperature profiles at different time instants for R4-36 at 12LPM

Figure 5-2 and Figure 5-3 shows that the magnitude of drop in surface temperature for the entry coil sets were similar due to the fixed mains inlet water conditions. This was not the case for the exit coil sets. In that case, the change in surface temperature was highly dependent on the DWHR system length and flowrate. When comparing coil set temperature profiles for R3-36 and R3-60, it was noticed that longer DWHR systems induced more heat transfer from drain water, because the mains water had to travel a longer distance until it reached its exit point.

Secondly, for longer DWHR systems, more surface area was available for heat transfer. Since the mains water was retaining more heat near its exit point, this was the reason why the surface temperature of the exit coil sets was warmer than the ambient conditions once quasi-steady-state like conditions were reached.

The surface area to induce heat transfer also increased with increasing the drain-side diameter of DWHR systems, but it didn't have a significant impact on the exiting coil sets surface temperatures. For both R3-36 and R4-36, very similar surface temperature profiles were observed. This could be a result of uneven drain-side wetting of R4-36 due to its larger diameter and surface area [5]. If the annular film was not formed completely on the drain-side, there would not be sufficient heat transfer to the mains-side water and coils.

Flowrate had a strong impact on the exiting coil set temperatures for R3-36 and R3-60 but a weak impact on R4-36. A comparison of coil set and water temperature profiles showed that as the flowrate decreased, the exit coil sets heated up more as compared to the higher flowrates for both R3-36 and R3-60. This was because at lower flowrates, water in the mains-side coils took a longer time period to exit the coils of DWHR system. This prolonged delay induced more heat transfer from the warmer drain-side water. In other words, the mains water in coils got more time to collect extra energy from the warmer drain water.

The wider drain-side diameter of R4-36 required complete drain-side wetting in order to maximize the heat transfer. It has been proven that for 4" drain-side diameter DWHR systems, a flowrate of 5.5LPM only achieved partial wetting [5]. All the steady-state tests conducted by Beentjes et al. started with a really high flowrate in order to achieve full wetting of the drain-side pipe. Thereafter, the flowrates were dropped as desired to estimate effectiveness. For all the transient experiments conducted in this thesis, the flowrate was adjusted before each test as mentioned in Section 2.5.1. Hence, there is no evidence that for the 4" drain-side diameter DWHR systems, complete wetting was achieved even for higher flowrates. This was one of the reasons why flowrate seems to have a weak impact on the surface temperature of the exit coil sets for R4-36.

5.2.2 Energy Balance on Selected DWHR Systems

5.2.2.1 Energy Balance Overview

So far, the only useful information derived consisted of surface and water temperature profiles across the mains-side of the DWHR system. Temperature profiles behaved differently for all coil sets. Even though the coil set temperature profiles reached steady-state around the same time, there were still slight variations in the time to reach steady-state. This was because all the coil sets had slightly different thermal time response from each other. Hence, the conclusions derived about temperature response would not provide any useful insight about estimating the steady-state time response of DWHR systems. More information regarding the DWHR system behaviour was required in order to estimate that parameter. In other words, all coil set temperature profiles must be combined in a way such that the overall behaviour of the DWHR system could be analyzed.

Overall heat transfer to the mains-side water is one important parameter which has been used to characterize the performance of DWHR systems under steady-state conditions. It has been widely used to characterize heat recovery from the drain water. The same parameter can also be used to determine the time response of the selected DWHR systems in this experiment. Thermal time response is the time taken for the selected variable to reach quasi-steady-state conditions. So far, a generalized approach has been used to estimate q_{flow} based only on T_{ci} and T_{co} at steady-state conditions. Constant flowrate and specific heat capacity of water were assumed and q_{flow} was estimated using Equation 2.8. Energy storage effects were not considered. The main reason for such a simple approach was the lack of available information regarding temperature.

Infrared thermography provided detailed surface and estimated water temperatures across the entire DWHR system. Hence, the energy balance shown in Figure 2-1 was expanded to include the thermal storage effects (Equation 2.5). Once a detailed energy balance was applied to include those effects, heat recovery rate (shown by Equation 2.3) from the drain water was estimated with more precision.

5.2.2.2 Energy Balance Method Set-Up and Limitations

Energy storage is the combined effect of temperature change, flowrate, fluid properties and DWHR system's thermal properties. It is also dependent on the DWHR system response. Hence, all the derived information from the camera coil sets, RTDs and thermocouples in the previous sections were used to determine the energy storage in the selected DWHR systems. Once the heat energy recovery values were determined for each time instant and plotted against time, it was used to determine the time response in terms of energy recovered. The entire energy analysis was highly dependent on all measured surface and water properties. Therefore, expressing the time response of DWHR systems in terms of the system energy was the best approach. The first step to determine the energy terms was to simplify the overall energy balance equation.

It is important to note that energy balance in Figure 2-1 and Equation 2.3 was applied individually to each coil set. The resultant mains-side heat transfer rate (q_c) from each coil set was added throughout the DWHR system for each time instant to get the final result.

All variables in Equation 2.3 represents the properties of mains-side water at different time instants and coil set locations. Equation 2.3 is made up of 2 terms which represent the flow and storage energy associated with water in different coil sets respectively. In Equation 2.3, V is the internal volume of each coil set in m^3 , ρ is density of water in each coil set with units of kg/m^3 and dT/dt is the rate of change of water temperature in each coil set when compared to previous time instants.

q_c is the mains-side heat transfer rate to the water in each coil set with units of kW. The only new term that has been added to q_{flow} included storage effects.

To perform energy balance, a complete thermal network across the entire DWHR cross-section couldn't be drawn. The only available surface temperatures were at the coil sets exposed to the thermal camera. In order to draw a complete thermal network across the entire DWHR system cross-section, surface temperature profile of copper must be known for the entire cross-section which is not exposed to the thermal camera; along with the change in drain-side water temperature as the film falls and loses heat. Therefore, it was not possible to draw a thermal resistance network from the drain-side water through the coil set into the mains-side water at

each coil set section. Since none of that information was available, a simplified energy balance (including storage) was applied with the available information of estimated mains-side water temperature in the coil sets.

Moreover, the water flow behaviour in the coil sets was also unknown. It could not be determined whether the water flow was laminar or turbulent across the coil sets. This was the limiting factor because flow in non-circular helical coils have not been studied extensively. Hence, the convection coefficients calculated in Section 4.4.6 were not used to find the convective heat transfer (q_{conv}) in water. This is the reason why it was also not included in the energy balance.

It was assumed that the flowrate and water properties were constant in each coil set. They were based on the water temperature in the coil set of interest at any given time instant. Moreover, the coil sets were presumed to be completely filled with water at all given time instants in order to simplify the energy balance analysis.

A calculation sample for both the terms in Equation 2.3 will be shown and combined to determine q_c . Calculations were performed for the same sample scenario which was shown in Section 4.4.6.2. The density (ρ) and specific heat capacity (c_p) of water for sample calculation scenario are stated in Table 4-6. All the calculations for the energy balance were performed on coil set to coil set basis.

5.2.2.3 Flow Energy Rate Calculations

The first energy term calculated from Equation 2.3 was the change in flow energy of mains-side water as it entered and exited each individual coil set. Since the mains-side water temperature was expected to increase as it travelled through each coil set and gained heat from the drain-side as shown in Figure 5-1, the change in energy transfer rate to the mains water would be positive. Flow energy transfer rate at coil sets was thus calculated using Equation 2.4.

In that equation, \dot{m} is the mass flowrate of water and is calculated from the measured flowrate as follows:

$$\dot{m} = \left(\frac{12.08 \text{ L}}{\text{min}} \right) \left(\frac{1 \text{ min}}{60 \text{ s}} \right) \left(\frac{1 \text{ m}^3}{1000 \text{ L}} \right) \left(\frac{999.83 \text{ kg}}{\text{m}^3} \right) = 0.2012 \frac{\text{kg}}{\text{s}}$$

In order to find the difference between coil set outlet and inlet temperature, it was assumed that the water temperature at the coil set entry and exit was the same as the

temperature of water in the coil set prior and the current coil set. For example, since coil set 4 was being shown for sample calculation, T_{in} and T_{out} were the water temperatures at coil set 3 and 4 respectively. Hence, T_{in} and T_{out} were the water temperatures at the non-dimensionalized distance of 0.20 and 0.27 respectively as shown in Table 4-4 for the 200 seconds time instant. Based on all the known parameters, change in flow energy rate was calculated as:

$$q_{flow} = \left(\frac{0.2012 \text{ kg}}{s} \right) \left(4.1882 \frac{\text{kJ}}{\text{kgK}} \right) (12.69 - 12.05) \text{ K} = 0.5393 \text{ kW}$$

Hence, for R4-36 at 12LPM and 200 seconds time instant, coil set 4 experienced the flow energy rate change of 0.5393kW. The same procedure was applied to calculate energy for each coil set. Both flow and storage energy calculations for all the coil sets at sample calculation scenario are summarized in Table 5-2 at the end of Section 5.2.2.5.

5.2.2.4 Energy Storage Rate Calculations

Energy storage in mains-side water is represented by the second term in Equation 2.3 and is shown in Equation 2.5 [46].

In Equation 2.5, V represented the volume of water in the coil set of interest at a given time instant. The volume of water in the coil sets was measured physically for all 3 DWHR systems in order to improve accuracy of the storage terms. In order to do that, all 3 DWHR systems were weighed with and without water in the coil sets. Once the mass of water drained from the coil sets was determined, it was converted to the volume of water in each coil set. All the summarized data regarding the fluid mass and volume in the coil sets is shown in Table 5-1.

The density of water used to convert from mass to volume of water was based on the ambient room temperature of 23.8°C on the specific date when these measurements were taken. Linear interpolation led to the approximate density of water to be 997.6 kg/m³ [28].

Table 5-1: Calculations of volume of water in coil sets for selected DWHR systems

DWHR pipe	Mass of Empty Pipe (kg)	Mass of Pipe and Water (kg)	Mass of Drained Water (kg)	Volume of Water in all Coil sets (m ³)	Volume of Water in each Coil sets (m ³)
R3-36	7.847	8.666	0.819	8.21E-04	5.86E-05
R3-60	12.435	13.770	1.335	1.34E-03	5.57E-05
R4-36	10.834	12.150	1.317	1.32E-03	9.43E-05

For R4-36, calculations for volume of water in coil sets is shown as follows:

$$\text{Mass of Drained Water} = 12.150 - 10.834 = 1.316\text{kg}$$

$$\text{Volume of water in all Coil Sets} = \frac{1.316 \text{ kg}}{997.6 \text{ kg/m}^3} = 0.001319\text{m}^3$$

$$\text{Volume of Water in Each Coil Set} = \frac{0.001319\text{m}^3}{14 \text{ coil sets}} = 9.43 \times 10^{-5} \text{ m}^3$$

The last term to be determined for estimating the energy storage rate was dT/dt , which is the rate of change of water temperature at each coil set for different time steps. For the tests conducted in this experimental study, it represented the difference in water temperature between the current and the previous time instant. Based on the same calculation parameters used in previous sections, it was determined from Table 4-4 that:

$$\frac{dT}{dt} = \frac{T_{\text{water},200 \text{ sec}} - T_{\text{water},100 \text{ sec}}}{200 - 100} = \frac{12.69 - 12.81}{200 - 100} = -0.0012 \frac{\text{K}}{\text{s}}$$

Hence, with all the given information and using Equation 2.5, the storage energy rate of change for R4-36 coil set 4 at 200 seconds time instant was determined to be $-4.74 \times 10^{-4} \text{ kW}$ or -0.474 W .

$$q_{\text{storage}} = \left(\frac{999.83 \text{ kg}}{\text{m}^3} \right) \left(4.1882 \frac{\text{kJ}}{\text{kgK}} \right) (9.43 \times 10^{-5} \text{ m}^3) \left(-0.0012 \frac{\text{K}}{\text{s}} \right) = -0.474 \text{ W}$$

5.2.2.5 Resultant Heat Transfer Rate

The resultant rate of heat transfer to water in coil set 4 was therefore computed by adding up both the calculated flow and storage energy terms in Equation 2.3.

$$q_c = \dot{m}c_p(T_{\text{out}} - T_{\text{in}}) + \rho c_p V \frac{dT}{dt} = 0.5393\text{kW} + (-0.000474\text{kW}) = 0.5388\text{kW}$$

Heat transfer rates for the sample calculation scenario and other coil sets are summarized in Table 5-2. MATLAB scripts used for interpolation of fluid properties and calculating the flow energy transfer and storage rate are shown in Appendix L.

Table 5-2: Energy balance approximations at sample calculation scenario along with all other coil sets

Coilset	Flow (kW)	Storage (kW)	Coil set q_c (kW)
1	0.5400	-0.0004	0.5396
2	0.5399	-0.0004	0.5395
3	0.5397	-0.0004	0.5393
4	0.5396	-0.0004	0.5392
5	0.5394	-0.0004	0.5390
6	0.5393	-0.0004	0.5389
7	0.5391	-0.0004	0.5387
8	0.5390	-0.0004	0.5386
9	0.5388	-0.0004	0.5384
10	0.5387	-0.0004	0.5383
11	0.5385	-0.0004	0.5381
12	0.5384	-0.0004	0.5380
13	0.5383	-0.0004	0.5379
14	0.5382	-0.0004	0.5378
exit	0.5381	0.0000	0.5381
TOTAL q_c	8.0848	-0.0055	8.0793

The last column in Table 5-2 shows the overall mains-side heat transfer rate (q_c) in each coil set as derived from Equation 2.3. In order to compute the overall heat transfer rate for the entire DWHR system length for any time instant, all heat transfer rates for all coil sets were added up together.

Table 5-2 shows that for R4-36 at 200 seconds time instant when the flowrate was 12LPM, the overall heat transfer rate to the mains-side water was 8.0793kW.

5.2.2.6 Energy Balance Plots and Storage Effects

The total mains-side heat transfer rate (q_c) indicated in the last row of Table 5-2 is the key value of interest. It could be used to analyze the thermal time response for all 3 DWHR systems at the flowrates studied because it is a combined effect of flowrate, water inlet and outlet temperatures, surface temperature of coils etc. Table 5-3 shows the summarized overall heat transfer rates of R4-36 at 12LPM for all time instants. Figure 5-4 shows the energy balance plot which includes the calculation scenario and is the graphical representation of Table 5-3. Plots for all of the 18 tests are shown in Appendix O.

Table 5-3: Energy balance approximations for R4-36 at 12LPM

Time (s)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.1716	0.0000	0.1716
2	0.7959	-2.0377	-1.2418
3	1.3223	-1.7075	-0.3852
5	3.0291	-2.8104	0.2187
8	5.0710	-1.9849	3.0861
10	5.9369	-1.1581	4.7788
15	7.1637	-1.0591	6.1045
20	7.9415	-1.1036	6.8379
30	8.0268	-0.5547	7.4721
50	7.9211	-0.2500	7.6711
100	8.0008	-0.0383	7.9626
200	8.0848	-0.0055	8.0793

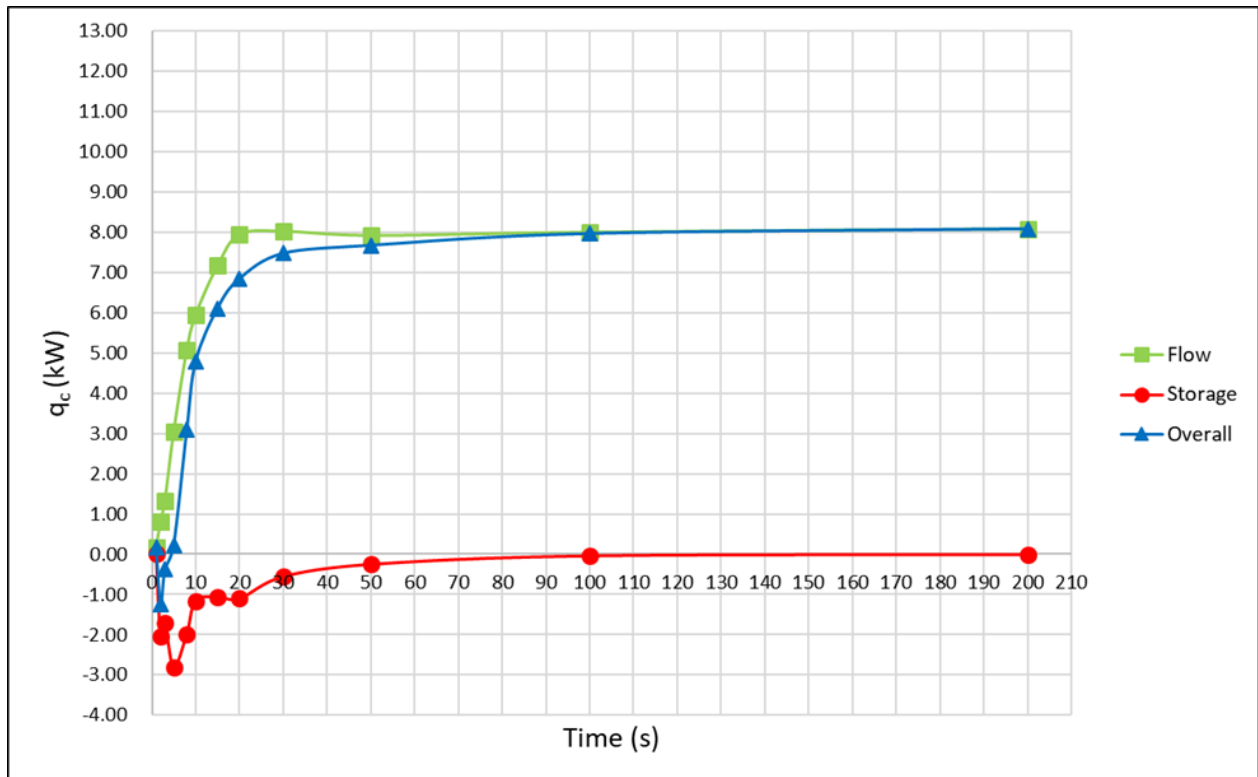


Figure 5-4: Mains-side energy balance plot for R4-36 at 12LPM

5.3 Discussions for Test Method 2

5.3.1 Overall Energy Balance Discussion

Figure 5-4 shows 3 different plots for 1 of the 18 tests conducted. The overall mains-side heat transfer rate (q_c) to the mains water was shown in blue triangular labels and was the summation of the flow energy input rate (green square labels) and storage energy rate (red circular labels). The slight overshoot in the flow energy term was most likely due to the time difference associated with fluid streams exiting the mains and drain-side. The ambient water in the mains-side would take longer to exit the system since it travels through the coils. Hence T_{co} would take longer to stabilize, as compared to drain-side water.

It was observed that the rate of energy storage for all 18 tests conducted was small and negligible. It did not have a big impact on the overall heat transfer rate. At the beginning of each test, the magnitude of the energy storage rate started to decrease sharply and peaked out. Thereafter, it started to increase and eventually settled at 0.

Once the test started, the existing water in the coil sets at ambient temperature conditions began to flush out and was being replaced with the mains water at about 10°C. Since the mains-side inlet water being filled in the coil sets was much colder than the exiting ambient temperature water, it resulted in the negative energy storage term. This meant that the mains-side water entering the coil sets during the very beginning instances of any test doesn't result in any useful energy storage.

The impact of warmer drain water was observed, after the water at ambient temperature cleared out of the mains-side coils. This impact was observed in the form of heat recovery which resulted in the energy storage term to peak out, and a positive slope was observed in energy storage terms. It is important to note that the rate of energy storage was always negative throughout the duration of each test. It was due to the fact that for most of the coil sets of any tests conducted, the dT/dt term which represented the change in water temperature in each coil set at different time instants ended up as a negative number. For example, if a test scenario had the exit coil set water temperature to drop from 22°C to 20°C from beginning to end of a test, the change in water temperature at that particular coil set would be negative throughout.

Since most of the dT/dt terms were negative, once the storage terms were added for all the coil sets to get the overall energy storage rate for any DWHR system at a specific time instant, the resultant value was negative energy storage rate. Even though energy was being recovered by the DWHR system in form of warmer water temperature at the mains outlet side, the negative dT/dt term indicated that at the coil set level, water temperature was decreasing throughout the test.

The nature of the energy storage terms seemed to be highly dependent on the pre-set starting initial conditions. It was presumed that if the remaining water from any previous tests in the coil sets could be kept at a much lower temperature as compared to the ambient, or if the mains-side inlet water was set to a much higher temperature, the rate of energy storage terms would turn out to be positive. This is because if the remaining colder water in the coil sets from the previous tests was replaced during the test duration with the warmer mains water, the dT/dt term would always be positive and in turn would result in positive storage terms.

From the energy balance plot shown in Figure 5-4, it was concluded that the general shape of the energy balance curves for all the tests conducted were very similar. It was observed that the energy storage rate term dropped and peaked out generally within the first 10 seconds of a test. Thereafter, it started to increase and converged to 0kW around 1 minute mark of the test. This was the instant in time when the DWHR system had reached quasi-steady-state conditions, and the change in water temperature was negligible when compared at different time instants at a particular coil set location.

The magnitude of the storage term was small when compared with the flow energy terms. Flow energy transfer rate was the major component of the energy balance plots. It was observed that the storage terms played a major role in stabilizing the flow energy curves, to derive the overall energy balance plots especially for the higher flowrates. It was evident from Figure 5-4 where the slight uneven bump in the flow energy curve between 10 and 40 second mark was adjusted due to the addition of storage terms.

For all the cases, the flow energy rate and the overall energy transfer rate were very close to each other. This was even more visible for the lower flowrates because the storage terms were much smaller even during the beginning instances of the tests. For all the tests, as the system

reached steady-state, both the flow and overall energy transfer rate profiles were almost identical due to negligible storage. Hence, it was concluded that the storage terms only played a major role during the beginning of the tests by slightly adjusting the overall energy balance profile and eventually vanished.

The overall rate of heat transfer to the mains-side water was the most crucial part of the infrared thermography experiments. It represented the estimated rate of thermal energy extracted from the gray water. The shape of the overall energy transfer rate curve was similar for all 18 tests. In general, q_c seemed to increase exponentially at a much faster rate during the beginning instances of the test, and eventually reached steady-state condition.

It was observed that the change in the slope of q_c with respect to time was very steep at the beginning of the tests. The slope eventually evened out as the system reached steady-state approximately around the 1 minute mark for all the tests. This was the point in time when the system reached quasi-steady-state, and eventually the lines representing overall q_c flattened out. Another key observation made here was that due to the insignificant storage as compared to flow energy transfer rate, both the overall heat transfer rate and flow energy transfer rate were very similar to each other.

For each individual DWHR system, q_c decreased as the flowrate of water decreased through the coil sets. The major reasoning behind such observation was the decrease in flow energy transfer rate due to lower \dot{m} for lower flowrates. Since the flow energy transfer rate was a major component of the overall energy balance equation, any changes in the mass flowrate had a direct impact on q_c . The change in flowrate for each DWHR system also had an impact on the change in q_c during the beginning transient instances of a test with respect to time. This was evident by observing the slope of q_c during the first minute of each test for any particular DWHR system. For higher flowrates, q_c increased very quickly and reached quasi-steady-state in a shorter period of time as compared to lower flowrates, where the slope became less shallower and the time period to stabilize and reach steady-state increased.

When q_c was compared by varying the DWHR system drain-side length and keeping the same diameter as in case of R3-36 and R3-60, it was observed that increasing the drain-side length had a significant proportional impact on q_c at all 6 flowrates. This was observed by

comparing the energy balance plots for R3-36 and R3-60 at the same flowrates. This was due to the fact that the longer the DWHR system was, water in the coil sets would take much longer to exit at the mains-side outlet. This delay in the exit of mains water allowed for more heat to be extracted from the drain water. Moreover, longer DWHR systems had more surface area available for heat transfer to occur. As a result, at all flowrates q_c was higher for the DWHR systems with the longer drain-side length.

For DWHR systems of different diameter and constant drain-side length, a minor inverse impact on q_c was observed. This observation was made by comparing the energy balance plots for R3-36 and R4-36 at all flowrates. For a larger drain-side diameter DWHR systems, q_c slightly decreased for all flowrates. Even though R4-36 had more surface area for heat transfer as compared to R3-36, improper drain-side wetting could have been the reason behind lower q_c as compared to R3-36. Especially for the cases of lower flowrates, it was possible that the film of warmer drain water might not have been completely formed. This has already been explained in detail towards the end of Section 5.2.1 when the temperature profiles were discussed.

The drop in q_c was most significant when comparing R3-36 and R4-36 at 5.5LPM. This suggested that at such lower flowrates, the film did not form completely for the bigger drain-side diameter DWHR system. Hence, the difference in q_c was much larger as compared to all other flowrates. This also suggested that the quality of film formation diminished as the flowrate decreased, and the DWHR systems with bigger diameter were the most affected by it.

5.3.2 First Order Time Response Plots for q_c

The overall heat transfer rate (q_c) in Figure 5-4 resembled the first order exponential response of the form shown in Equation 5.1, where $q_{c,ss}$ represented the mains-side heat transfer rate at 200 seconds time instant, and τ_c was the time constant for mains-side heat transfer rate.

$$q_{c,correlation} = q_{c,ss} \left(1 - e^{-\frac{t}{\tau_c}} \right) \quad (5.1)$$

Figure 5-5 shows the first order q_c vs time plot for R4-36 at 12LPM. q_c and $q_{c, correlation}$ represents the experimental and correlational values of mains-side heat transfer rate. The coefficients for all 18 tests are shown in Table 5-4. $t_{99\%}$ in Table 5-4 represents the 99% steady-state time response of q_c for all 18 tests. Plots for all 18 tests are shown in Appendix P.

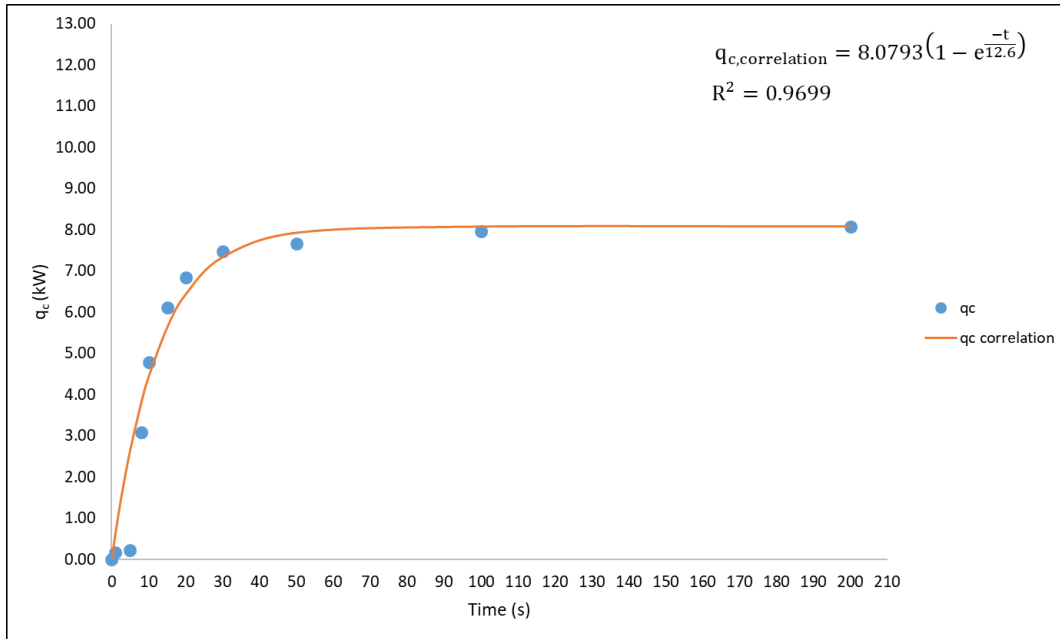


Figure 5-5: First order time response for R4-36 at 12LPM

Table 5-4: Coefficients for first order q_c vs time plots

	Flowrate (LPM)	$q_{c,ss}$ (kW)	τ_c (s)	R^2	$t_{99\%}$ (s)
R3-36	14	9.3534	10.0	0.9683	46.05
	12	8.3575	12.0	0.9641	55.26
	10	7.5465	13.5	0.9697	62.17
	9	7.0818	14.0	0.9833	64.47
	7	6.1279	18.0	0.9833	82.89
	5.5	5.2942	23.0	0.9779	105.92
R3-60	14	12.5457	9.50	0.9541	43.75
	12	11.3345	11.0	0.9605	50.66
	10	10.0763	14.0	0.9665	64.47
	9	9.2388	15.0	0.9746	69.08
	7	7.9102	19.0	0.9527	87.50
	5.5	6.5069	25.0	0.9677	115.13
R4-36	14	8.8437	10.0	0.9450	46.05
	12	8.0793	12.6	0.9699	58.03
	10	7.2982	13.5	0.9528	62.17
	9	7.0004	17.0	0.9715	78.29
	7	5.8290	20.0	0.9510	92.10
	5.5	3.8593	25.0	0.9637	115.13

Table 5-4 indicates that the steady-state time response could range from 45 seconds to about 2 minutes depending on the system flowrate. Even though most of the change in heat transfer rate occurs within the first 50 seconds, it may take up to 2 minutes for the system to reach complete steady-state.

5.3.3 Infrared Thermography Based Time Response

The last step in the study of infrared thermography of DWHR systems was the estimation of 63.2% and 86.5% time responses for all 18 tests, using thermography data. 63.2% and 86.5% q_c values were found by multiplying the q_c value at 200 seconds with 0.632 and 0.865 respectively. Linear interpolation was then applied to find $t_{63.2\%}$ and $t_{86.5\%}$ respectively. Table 5-5 shows the estimated time responses for the 3 DWHR systems based on the infrared thermography method.

Table 5-5: Experimental time responses based on thermography approach

Time (s)	Response	14LPM	12LPM	10LPM	9LPM	7LPM	5.5LPM
R 3-36	63.2%	14.08	15.92	17.11	16.70	21.29	28.07
	86.5%	19.91	25.60	27.99	28.23	40.14	48.34
R 3-60	63.2%	14.11	14.22	17.19	17.38	24.73	29.83
	86.5%	19.71	23.92	28.56	28.46	42.33	50.55
R 4-36	63.2%	14.44	11.23	17.70	18.92	28.20	23.74
	86.5%	22.35	22.38	28.18	42.12	99.61	65.25

5.4 Comparison of Time Responses for Both Test Methods

All the relevant conclusions regarding time responses have been made in Chapter 3. The purpose of estimating the time responses for thermography based experiments was to compare the derived results for both experimental approaches. The difference between thermography based time responses in Table 5-5 and generalized time responses in Chapter 3 from Table 3-4 and Appendix C are shown in Table 5-6. The thermography approach resulted in higher time responses than the generalized approaches in almost all the cases. This was due to the thermal lag associated with thermography. Water temperatures were being measured with a second or two of thermal lag.

Table 5-6: Difference between thermography based and generalized time responses

Time (s)	Response	14LPM	12LPM	10LPM	9LPM	7LPM	5.5LPM
R 3-36	63.2%	2.91	3.21	3.86	2.94	2.01	5.41
	86.5%	3.17	6.06	7.18	6.36	8.56	11.54
R 3-60	63.2%	2.57	1.48	3.05	0.50	2.86	3.17
	86.5%	0.52	3.63	4.88	1.60	5.81	5.94
R 4-36	63.2%	4.23	-0.17	3.50	3.54	11.97	2.42
	86.5%	5.47	4.25	3.33	18.18	74.35	29.48

Both methods resulted in very similar time response values for most of the cases. The time responses derived by both methods were off by only a few seconds for majority of the tests. This uncertainty will always be present for any measured transient time response due to its unpredicted nature.

The only problems observed were for the time responses of R4-36 at the lower flowrates. The significant time difference was solely based on the experimental error of the energy balance plot for R4-36 at lower flowrates, which could be accessed from Appendix O. All of the energy balance plots showed steady-state heat transfer during the ending phase of the thermography experiments, except for R4-36 at lower flowrates. This was most likely due to improper film formation and could be resolved if thermography is repeated on lower flowrates of R4-36.

Except for some cases, both approaches resulted in similar time responses. Hence, previous results from Chapter 3 were confirmed using the thermography approach. Any significant differences in results could be further investigated to remove any induced experimental errors.

Chapter 6 Conclusions and Recommendations

6.1 Conclusions

The focus of this thesis was to lay the foundations for studying the transient response of DWHR systems using a purely experimental approach. In general, different methodologies were developed to investigate the transient behaviour and time response of DWHR systems at equal-flow, under a fixed set of water inlet and CSA flowrate conditions.

Repeatability of the inlet and outlet water temperatures for the transient and steady-state duration was the first point that was established. All of the derived temperature data concluded that the temperature profiles were fully repeatable for the entire duration of any test, provided that the water inlet and ambient conditions stayed relatively the same. The temperature profiles were exponential in nature.

The first test method dealt with studying the time response of 11 DWHR systems using a generalized approach, in which q_{flow} was plotted as a function of time for the entire test duration. The profile of q_{flow} with respect to time was exponential in nature. 63.2% and 86.5% steady-state time responses were estimated for all the experiments. It was found that all the DWHR systems reached 63.2% and 86.5% steady-state within 35 to 50 seconds respectively. It was also determined that the time responses increased with increasing DWHR system's drain-side length and decreasing flowrate. Any deviations from the patterns observed were specific to DWHR system characteristics. Linear equations were used to best describe the time response based on flowrate and drain-side length. Validation for the generalized approach was completed by running some random tests and comparing the calculated and predicted time responses. The correlation established could predict the time response within ± 6 seconds.

The second test method focused on expanding the energy balance equation to include energy storage effects by using infrared thermography. Due to time consuming nature of transient testing and the limited availability of infrared camera, only 3 DWHR systems were tested once. The measured surface temperature of the mains-side coils was used to estimate the mains water temperature throughout the DWHR system length. It was concluded that the water temperature increased in a linear fashion throughout the length for all time instants.

A complete energy balance to estimate q_c , consisting of inlet and outlet and storage terms was performed on each set of coils for all the selected time instants. It was determined that storage only had an impact during the beginning phase of the tests. Storage played a role in stabilizing the energy balance curves by removing the uneven bump during the transient phases. For all the tests, the storage term was negative and eventually settled to 0kW as the system reached steady-state operating conditions. 63.2% and 86.5% time responses were derived and compared to the values in Chapter 3. It was concluded that even though both experimental methods resulted in similar time responses, thermography approach resulted in slightly higher time response values, due to thermal lag in the measured temperatures.

Fitting the first order exponential equation to the cold mains-side heat transfer rate (q_c) indicated that the DWHR systems would reach 99% steady-state response within the first 2 minutes for all the experiments.

6.2 Recommendations

There are several factors which could have had an impact on the estimation of time responses of DWHR systems. Firstly, the HXTP was primarily set-up to conduct steady-state testing. No modifications were done on the HXTP because of ongoing projects. All of the transient testing was conducted using the HXTP available in STRL and the data was analyzed to the best extent. This resulted in longer wait times in between different tests. Hence the first thing that should be done is HXTP modification such that more transient experiments could be conducted with minimal wait times.

Since all experiments started from 0 flowrate with a dry DWHR system, it was possible that complete annular film on the drain-side might not have been formed. Hence, it is highly recommended to modify the HXTP to ensure proper film formation. It will certainly improve the results and help in removing a significant portion of the experimental errors.

Transient analysis of DWHR systems is a very broad subject. Hence, a lot of experiments need to be conducted and results have to be validated for a lot of different cases, including different inlet conditions and flowrates. Some of the new cases could result from performing such analysis at unequal flowrates. More DWHR systems of different dimensions, especially drain-side length could be tested in future to further develop the relationships for time response.

Once the nature of time responses is fully established in the future, transient modelling of DWHR systems can be performed.

In addition to that, the availability of DWHR systems with varying dimensions from different manufacturers would greatly enhance in the development of the complete transient model.

It has been established that using infrared thermography is a good technique to determine DWHR system behaviour, since it removes the uneven bumps from energy balance plots. Hence more experiments can be conducted in the future using this approach, to further enhance research for DWHR system transient response and to model q_c plots as first order time response equations.

The response time can be slightly different each time the same test is repeated. Currently, there is no benchmark to compare the thermography induced response time of DWHR systems. Hence, the time responses derived in this work serve as a good approximation and benchmark for any future work that will be completed in this field. Infrared thermography experiments could be repeated again on current DWHR systems, or performed on more samples of different dimensions and length. Once the time responses for more DWHR systems are derived, more precise conclusions can be drawn regarding transient behaviour.

Computational Fluid Dynamics modelling could also be performed on the DWHR systems in order to study the transient behaviour with more accuracy. It would provide with a clearer picture of how the DWHR systems and the fluid behaves, along with more precise estimations of heat transfer and time responses.

There is a lot of potential for future improvements when it comes to performing infrared thermography on DWHR systems. The literature on transient behaviour and time response of DWHR systems could be expanded.

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Appendix A: Plots of Heat Transfer Rates for all 11 DWHR Systems

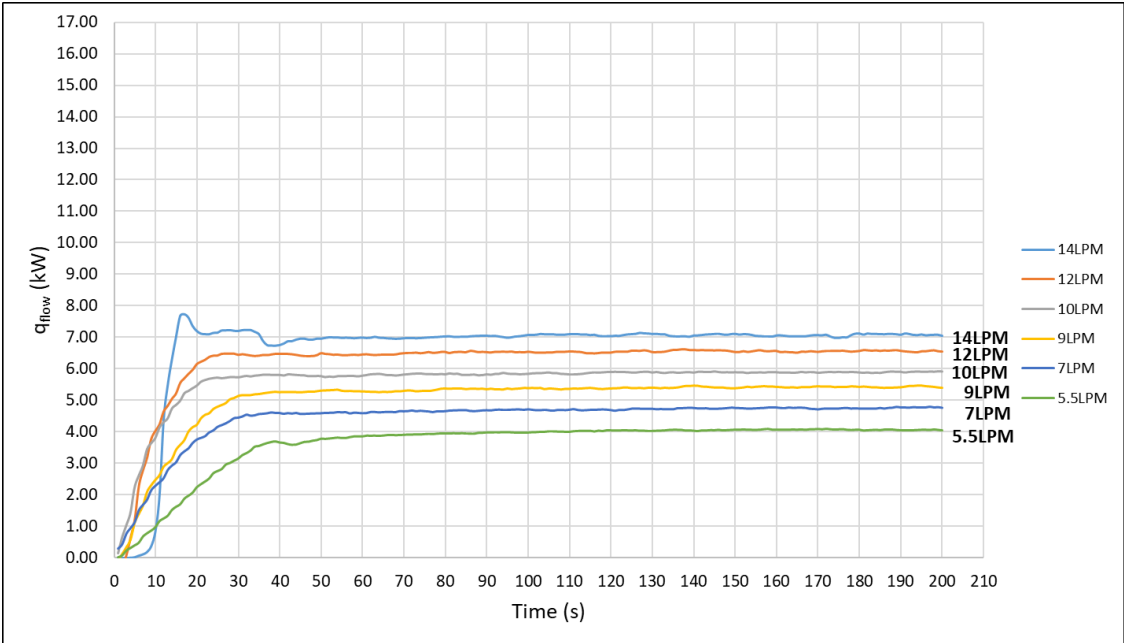


Figure A1: Calculated mains-side heat transfer rate for R2-36

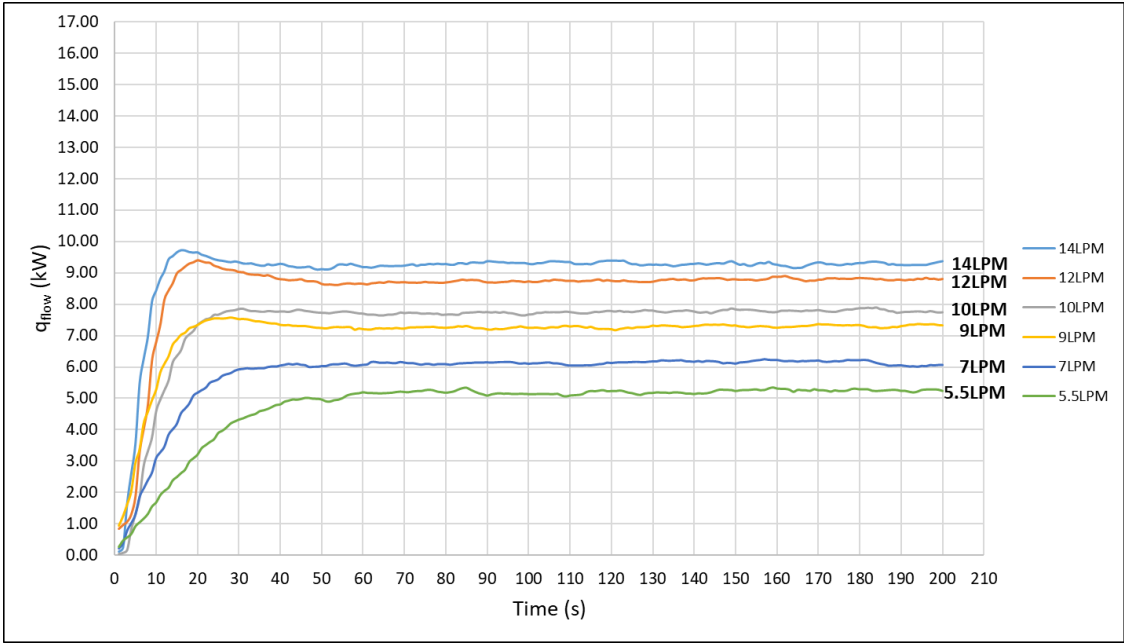


Figure A2: Calculated mains-side heat transfer rate for R2-48

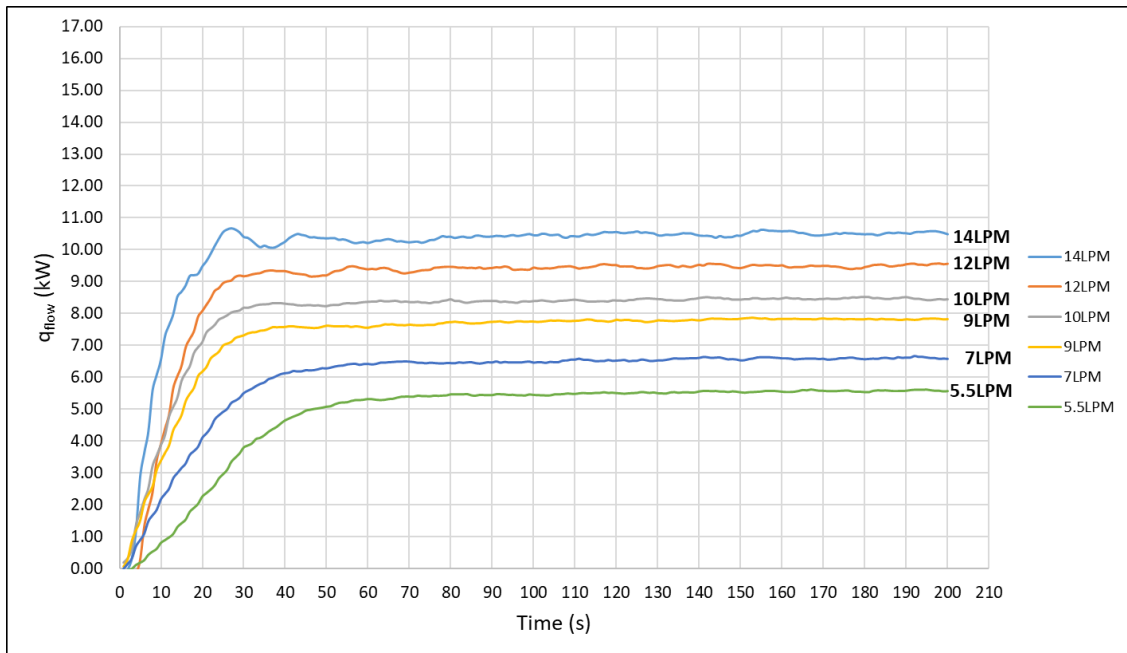


Figure A3: Calculated mains-side heat transfer rate for R2-60

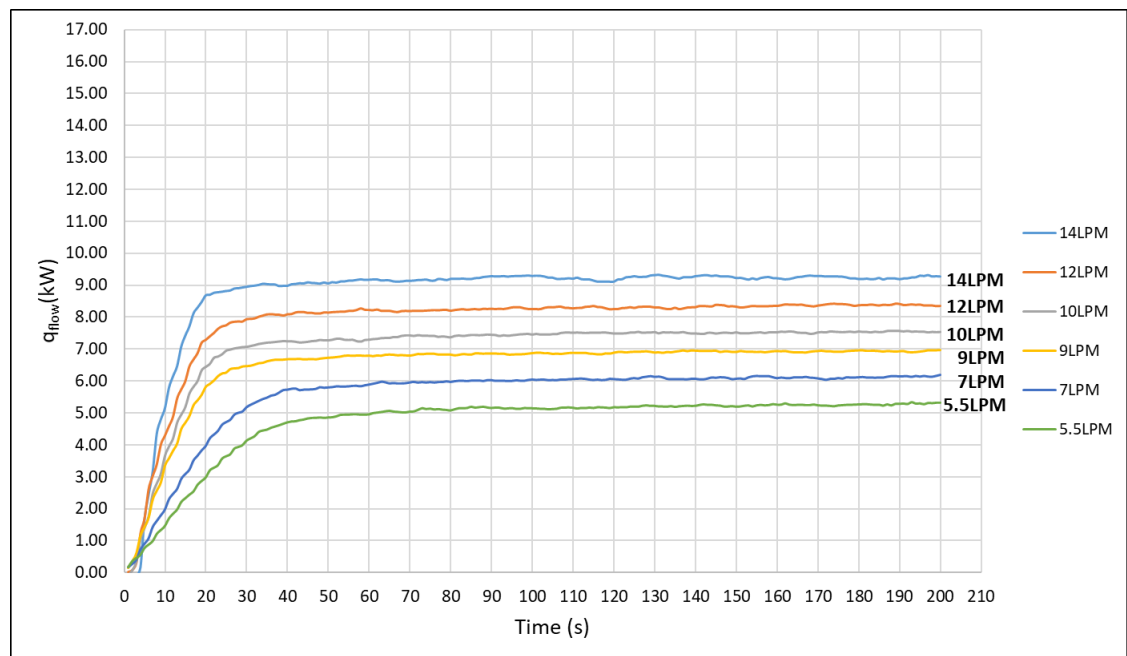


Figure A4: Calculated mains-side heat transfer rate for R3-36

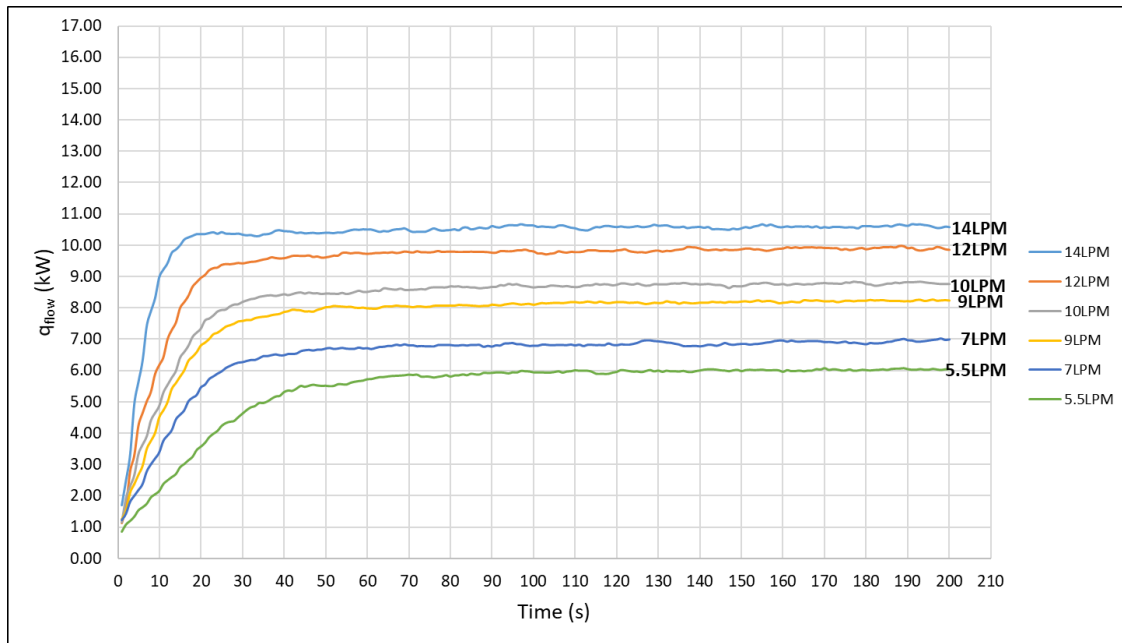


Figure A5: Calculated mains-side heat transfer rate for R3-48

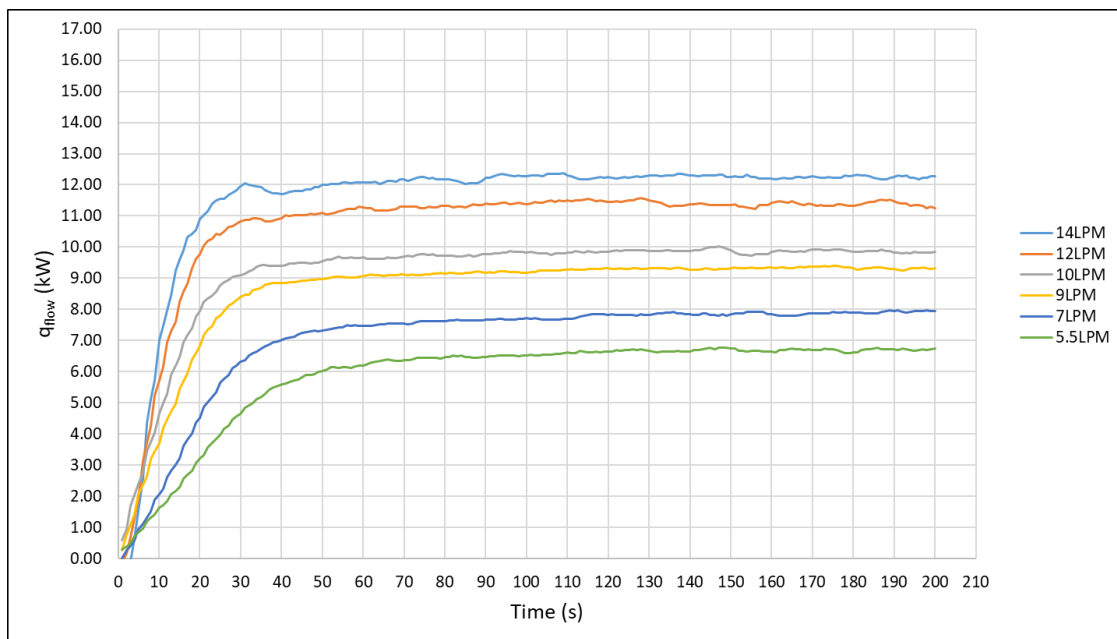


Figure A6: Calculated mains-side heat transfer rate for R3-60

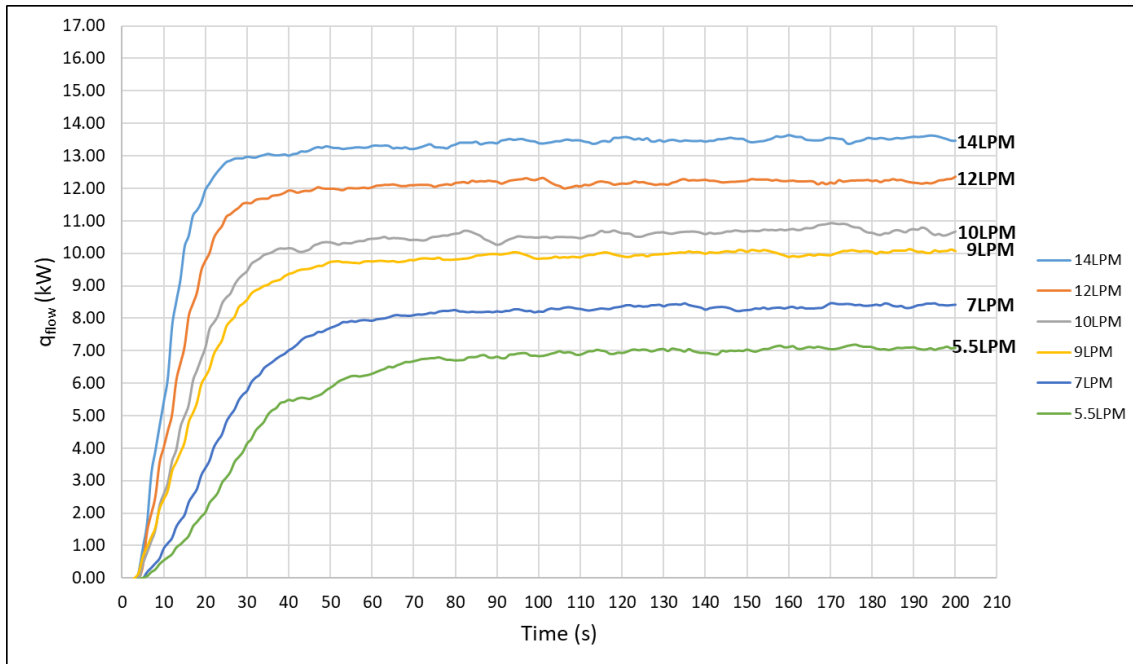


Figure A7: Calculated mains-side heat transfer rate for R3-72

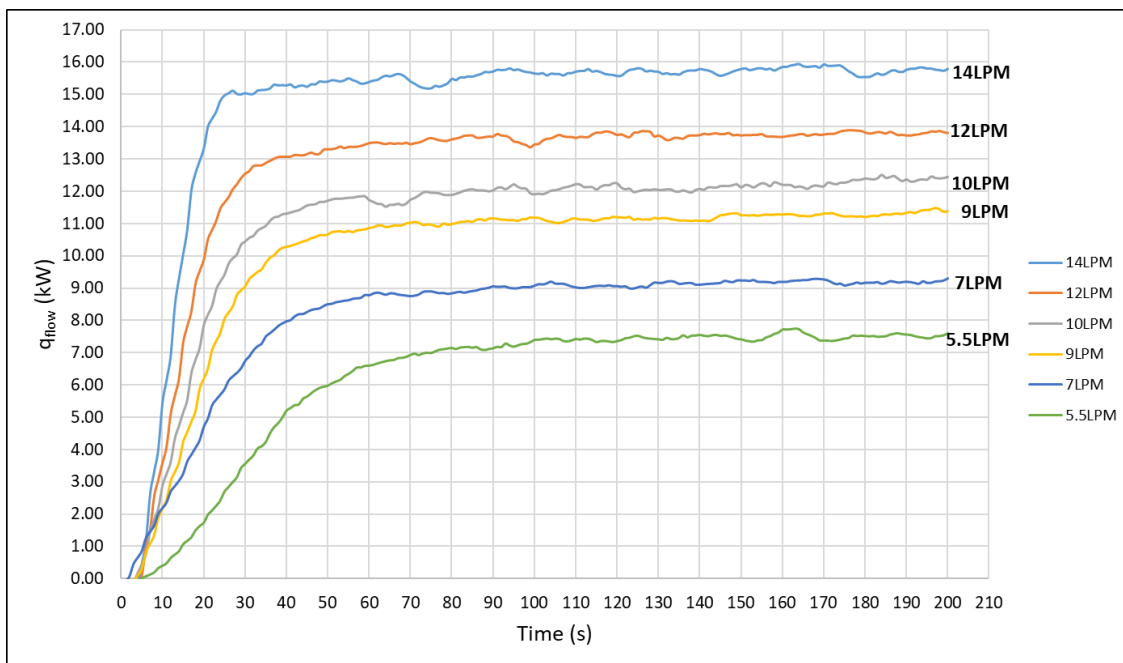


Figure A8: Calculated mains-side heat transfer rate for R3-84

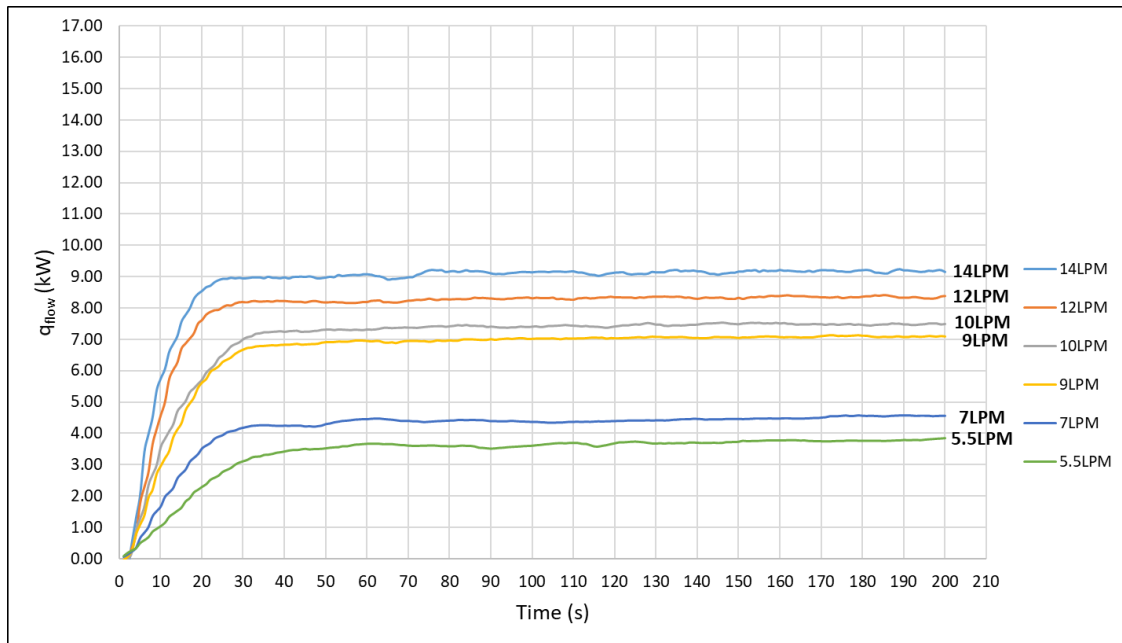


Figure A9: Calculated mains-side heat transfer rate for R4-36

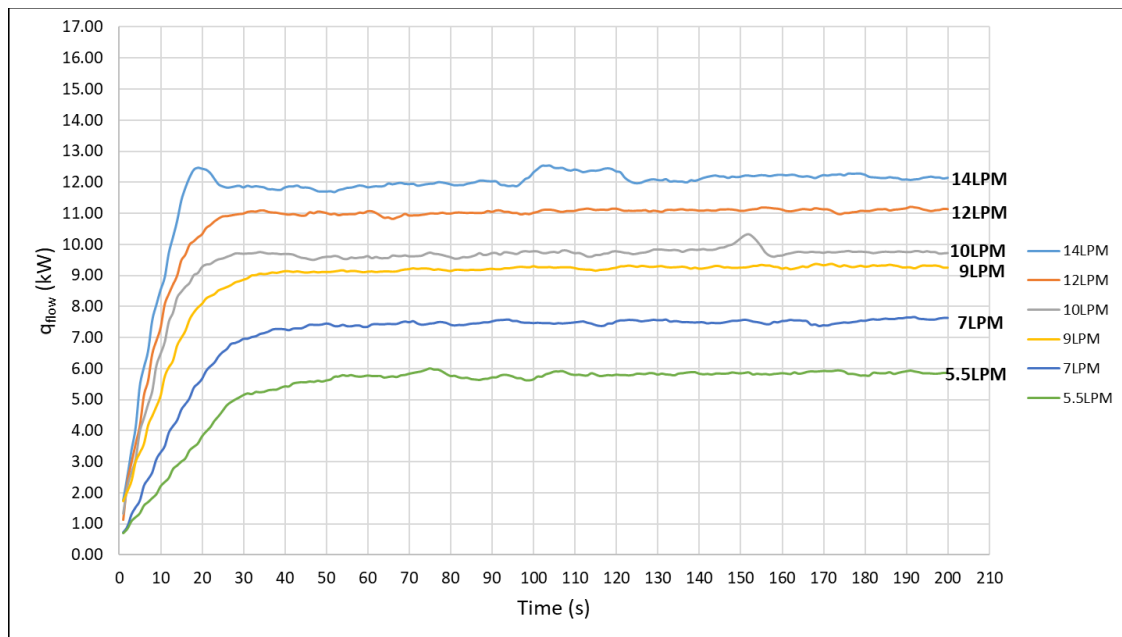


Figure A10: Calculated mains-side heat transfer rate for R4-48

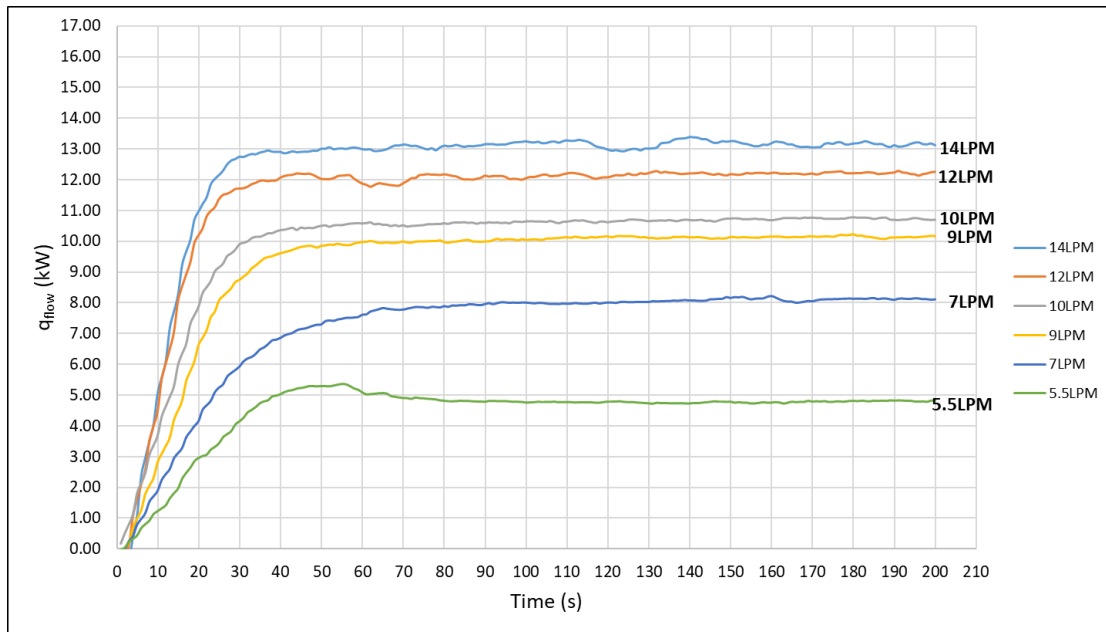


Figure A11: Calculated mains-side heat transfer rate for R4-60

Appendix B: 63.2% Response Time Data Tables and Plots

Note: Plots showing overall trends of 63.2% time response in thesis Chapter 3 are not presented in Appendix B.

Table B1: Difference between experimental and correlational time response all DWHR systems at CSA flowrates

Flowrate	R2-36			R2-48			R2-60			R3-72		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
14	12.09	8.92	3.17	6.57	5.22	1.35	10.15	8.67	1.48	13.04	11.46	1.58
12	10.60	11.34	-0.74	8.54	7.98	0.56	13.94	12.47	1.47	15.67	15.90	-0.23
10	9.50	13.76	-4.26	10.89	10.74	0.15	13.94	16.27	-2.33	19.01	20.34	-1.33
9	15.02	14.97	0.05	8.12	12.12	-4.00	15.32	18.17	-2.85	20.66	22.56	-1.90
7	14.90	17.39	-2.49	13.01	14.88	-1.87	20.53	21.97	-1.44	27.37	27.00	0.37
5.5	23.35	19.21	4.15	20.56	16.95	3.61	28.39	24.82	3.57	31.81	30.33	1.48
Flowrate	R3-36			R3-48			R3-60			R3-84		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
14	11.17	9.61	1.56	6.35	6.21	0.14	11.54	9.44	2.10	14.84	12.50	2.34
12	12.71	12.25	0.46	10.35	9.19	1.16	12.74	13.00	-0.26	17.52	17.16	0.36
10	13.25	14.89	-1.64	12.03	12.17	-0.14	14.14	16.56	-2.42	19.85	21.82	-1.97
9	13.76	16.21	-2.45	12.49	13.66	-1.17	16.88	18.34	-1.46	22.21	24.15	-1.94
7	19.28	18.85	0.43	13.86	16.64	-2.78	21.87	21.90	-0.03	24.72	28.81	-4.09
5.5	22.66	20.83	1.83	21.63	18.88	2.76	26.66	24.57	2.09	37.69	32.31	5.39
Flowrate	R4-36			R4-48			R4-60					
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)			
14	10.21	9.42	0.79	8.28	6.42	1.86	15.07	13.86	1.21			
12	11.40	11.84	-0.44	9.27	9.04	0.23	14.67	16.06	-1.39			
10	14.20	14.26	-0.06	9.23	11.66	-2.43	17.15	18.26	-1.11			
9	15.38	15.47	-0.09	11.43	12.97	-1.54	19.60	19.36	0.24			
7	16.23	17.89	-1.66	15.63	15.59	0.04	24.34	21.56	2.78			
5.5	21.32	19.71	1.62	19.61	17.56	2.06	21.74	23.21	-1.47			

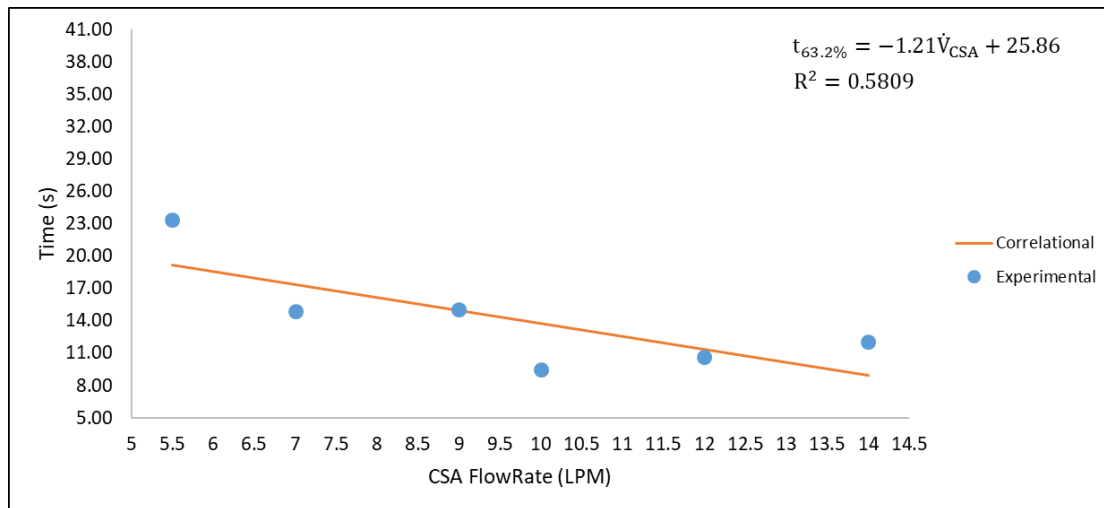


Figure B1: Experimental and correlational time response of R2-36 at different flowrates

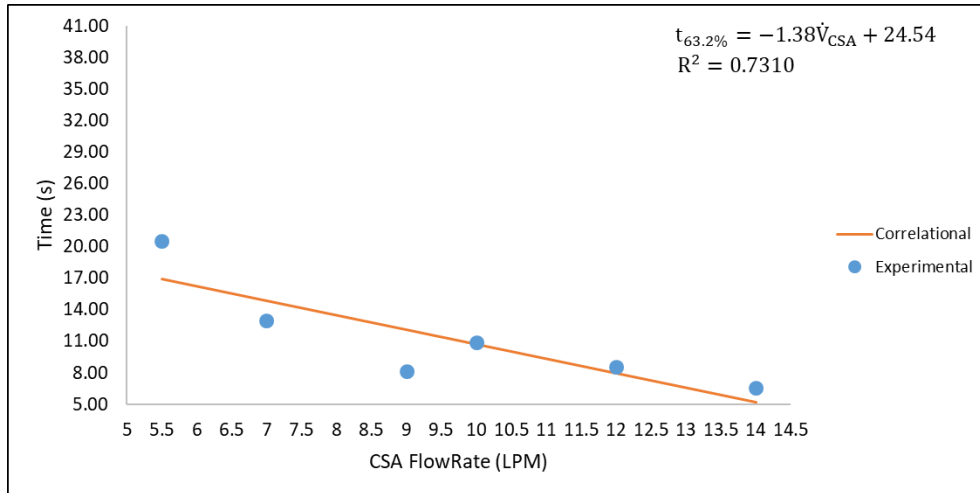


Figure B2: Experimental and correlational time response of R2-48 at different flowrates

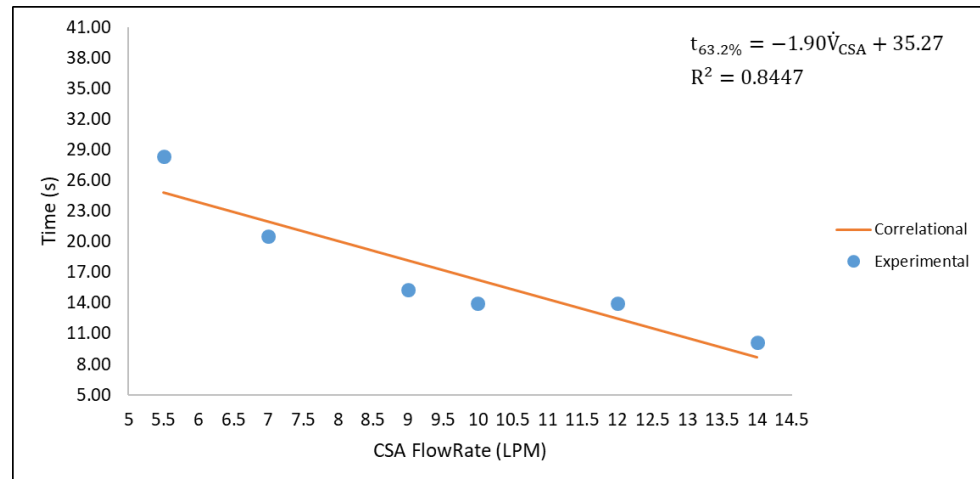


Figure B3: Experimental and correlational time response of R2-60 at different flowrates

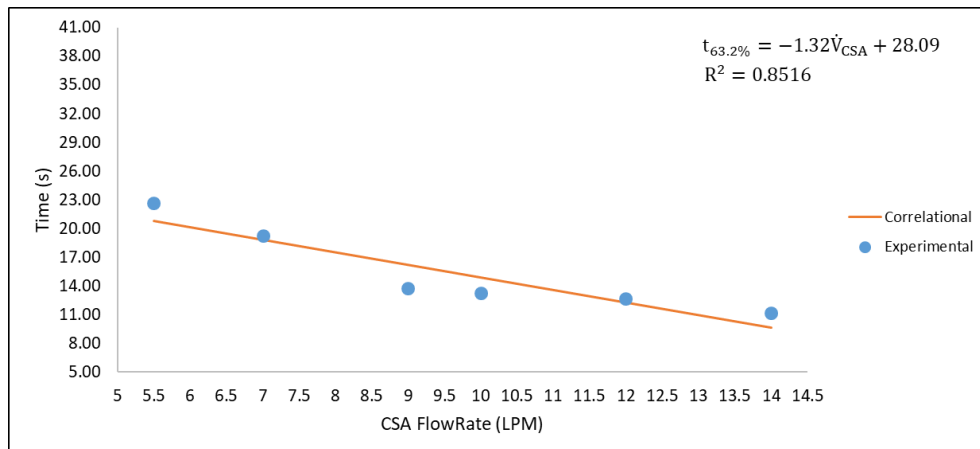


Figure B4: Experimental and correlational time response of R3-36 at different flowrates

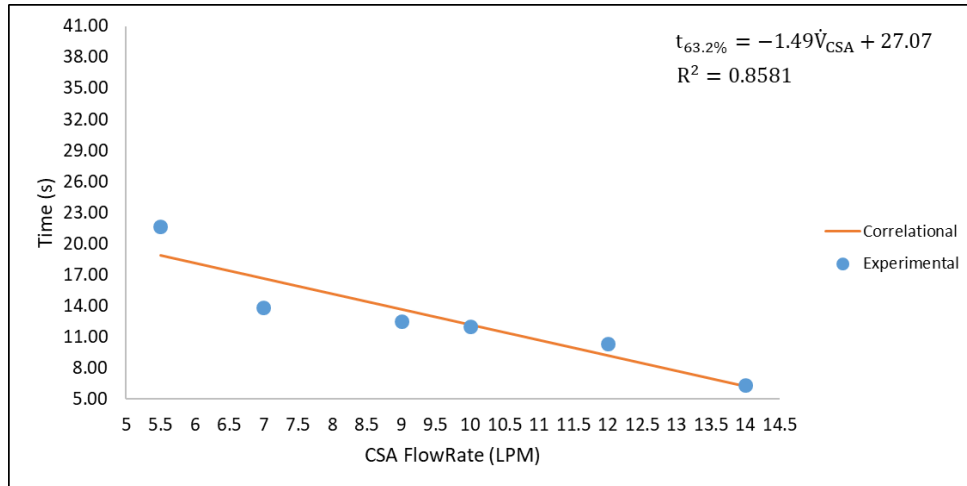


Figure B5: Experimental and correlational time response of R3-48 at different flowrates

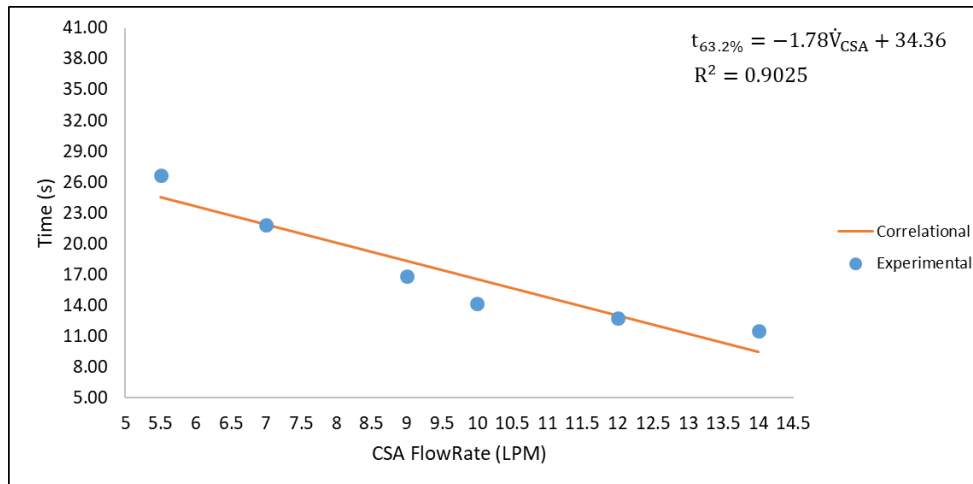


Figure B6: Experimental and correlational time response of R3-60 at different flowrates

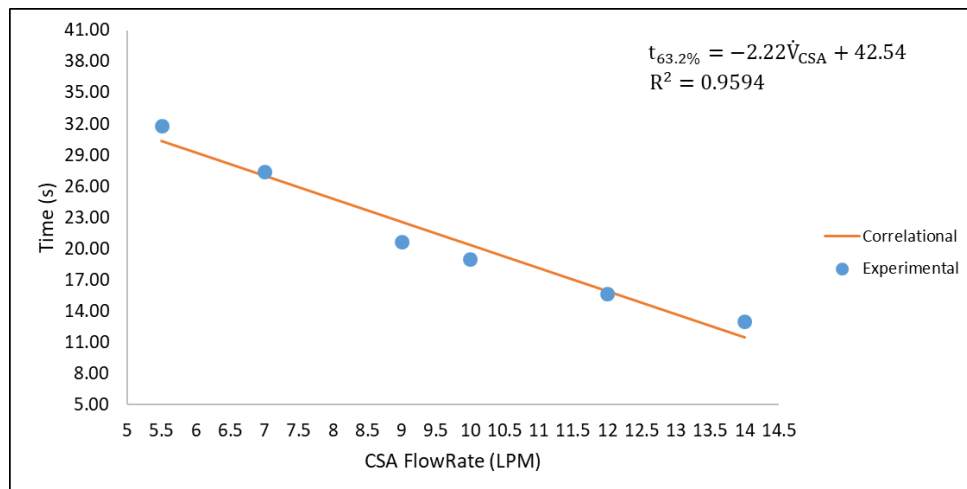


Figure B7: Experimental and correlational time response of R3-72 at different flowrates

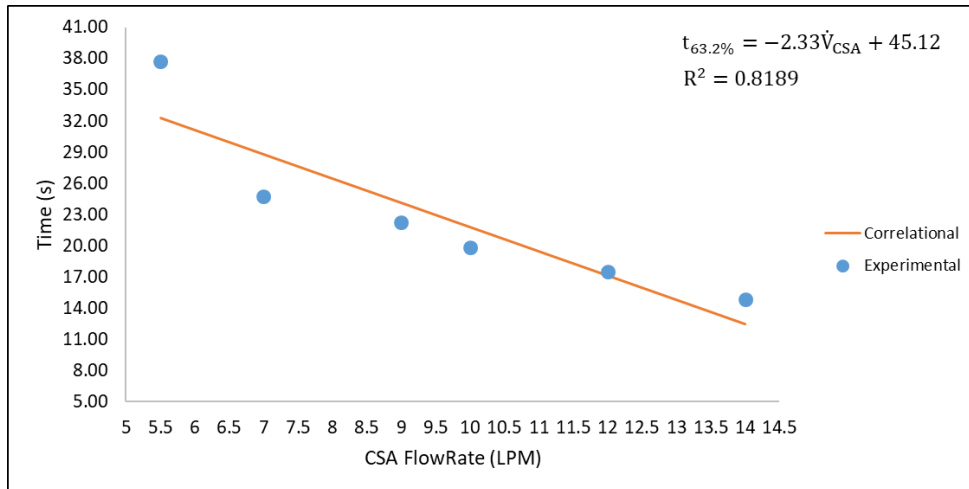


Figure B8: Experimental and correlational time response of R3-84 at different flowrates

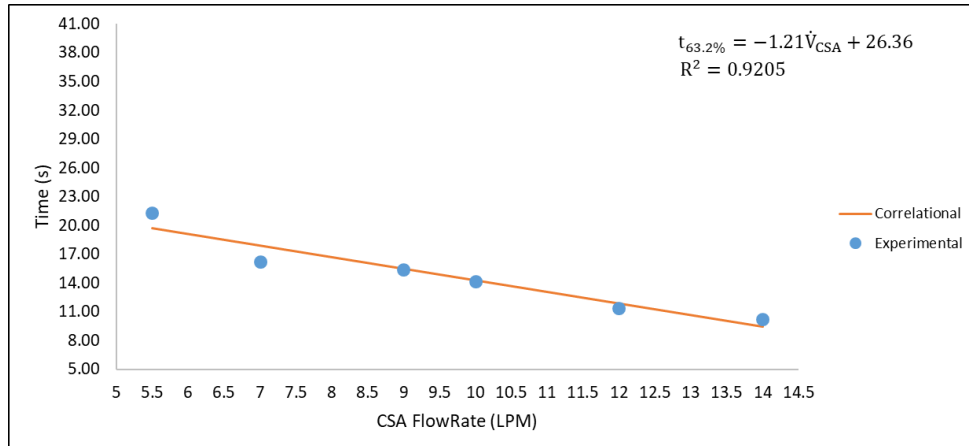


Figure B9: Experimental and correlational time response of R4-36 at different flowrates

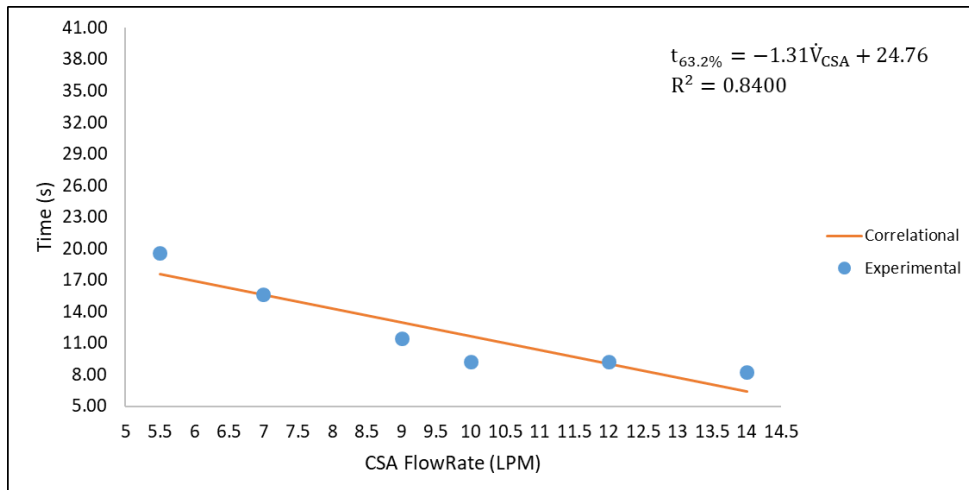


Figure B10: Experimental and correlational time response of R4-48 at different flowrates

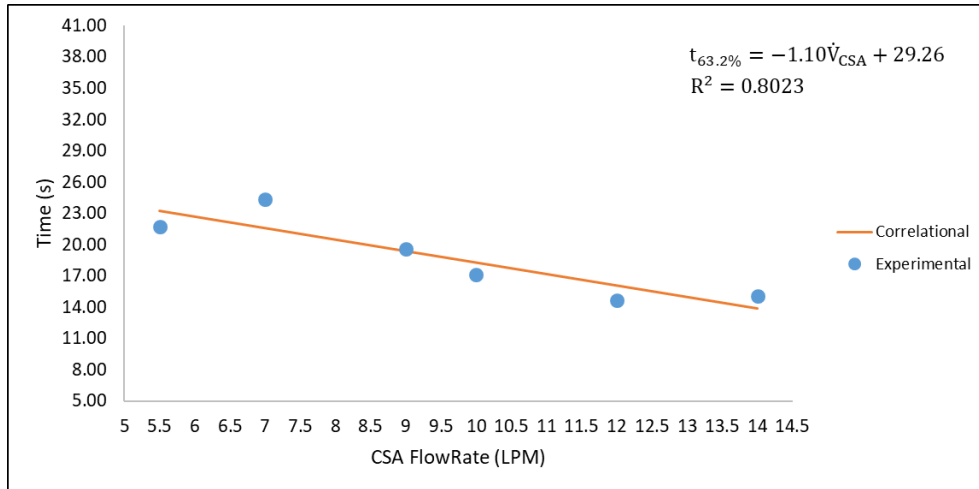


Figure B11: Experimental and correlational time response of R4-60 at different flowrates

Table B2: Difference between experimental and correlational time response of 3" drain-side diameter DWHR systems at CSA flowrates as a function of drain-side length

DrainSide Length	14LPM			12LPM			10LPM		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
36	11.17	8.69	2.48	12.71	11.00	1.71	13.25	11.69	1.56
48	6.35	10.13	-3.78	10.35	12.56	-2.21	12.03	13.73	-1.70
60	11.54	11.57	-0.03	12.74	14.12	-1.38	14.14	15.77	-1.63
72	13.04	13.01	0.03	15.67	15.68	-0.01	19.01	17.81	1.20
84	14.84	14.45	0.39	17.52	17.24	0.28	19.85	19.85	0.00
DrainSide Length	9LPM			7LPM			5.5LPM		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
36	13.76	12.23	1.53	19.28	16.42	2.86	22.66	20.21	2.45
48	12.49	14.75	-2.27	13.86	18.82	-4.96	21.63	24.29	-2.66
60	16.88	17.27	-0.39	21.87	21.22	0.65	26.66	28.37	-1.71
72	20.66	19.79	0.87	27.37	23.62	3.75	31.81	32.45	-0.65
84	22.21	22.31	-0.10	24.72	26.02	-1.30	37.69	36.53	1.16

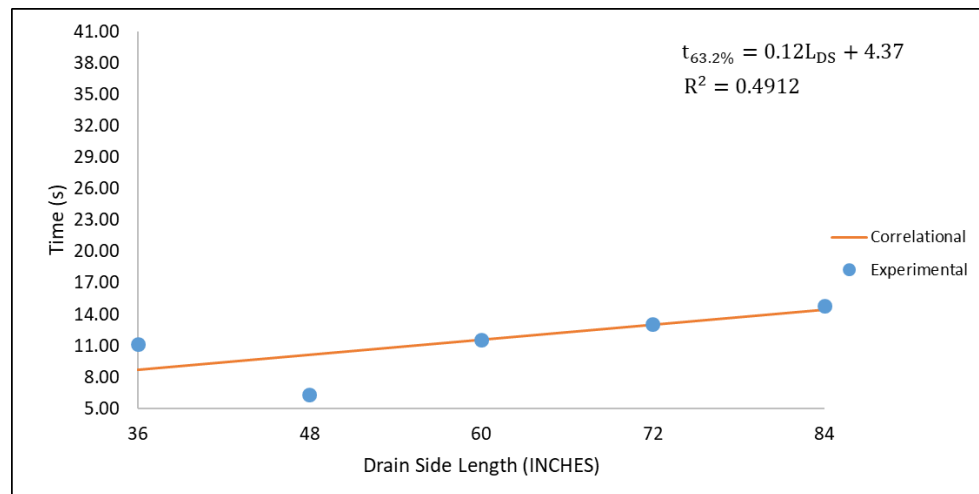


Figure B12: Experimental and correlational time response at 14LPM for all 3" drain-side diameter DWHR systems

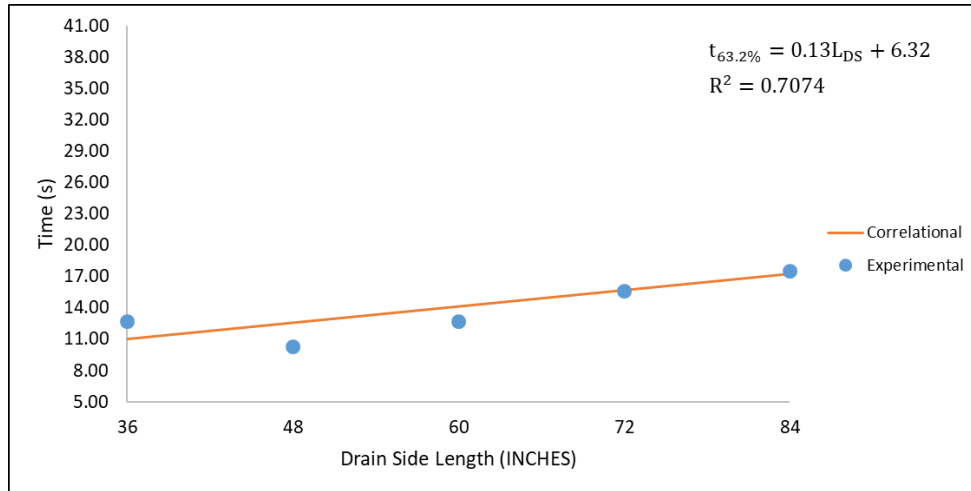


Figure B13: Experimental and correlational time response at 12LPM for all 3" drain-side diameter DWHR systems

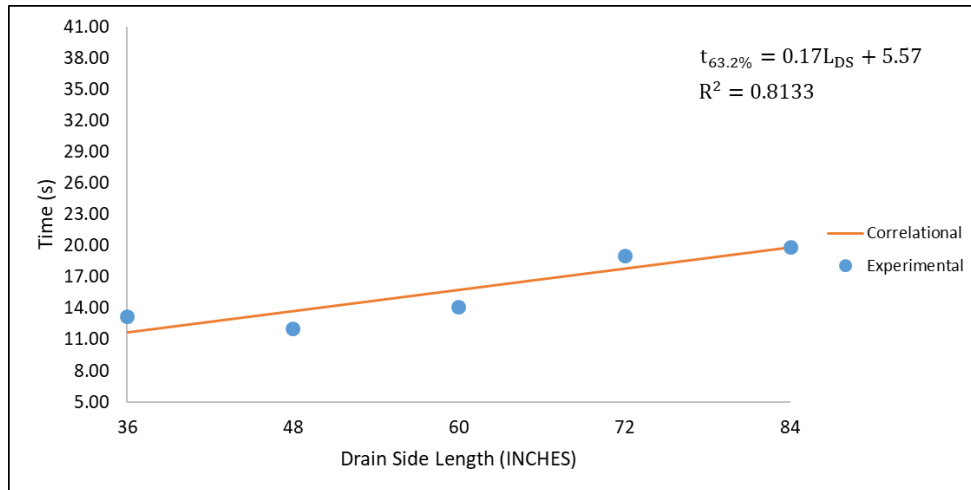


Figure B14: Experimental and correlational time response at 10LPM for all 3" drain-side diameter DWHR systems

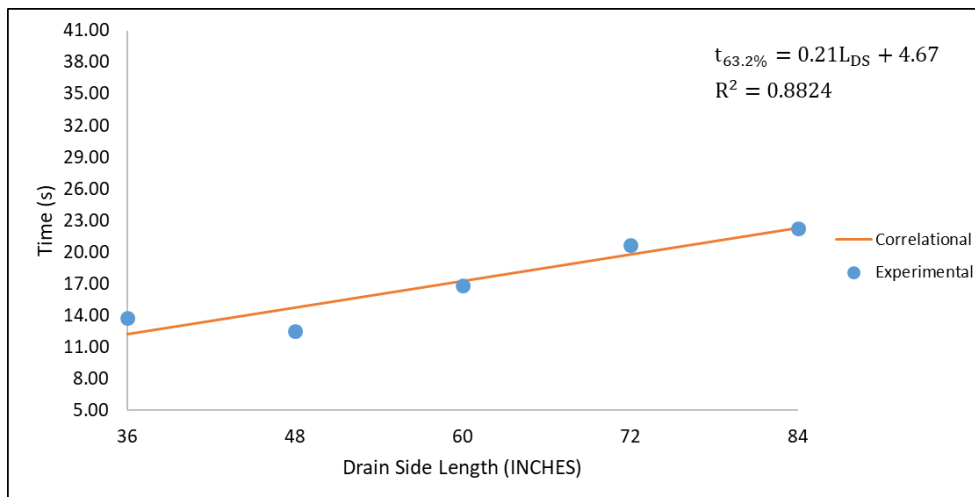


Figure B15: Experimental and correlational time response at 9LPM for all 3" drain-side diameter DWHR systems

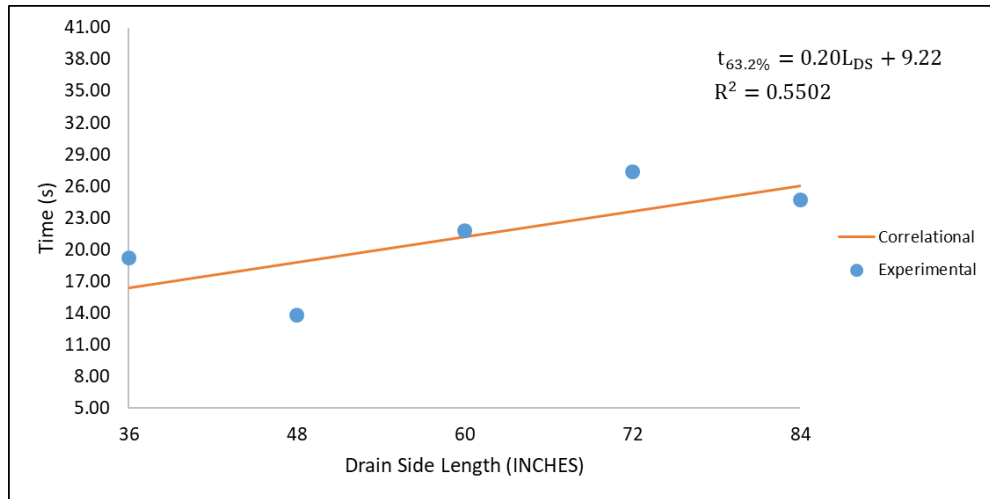


Figure B16: Experimental and correlational time response at 7LPM for all 3" drain-side diameter DWHR systems

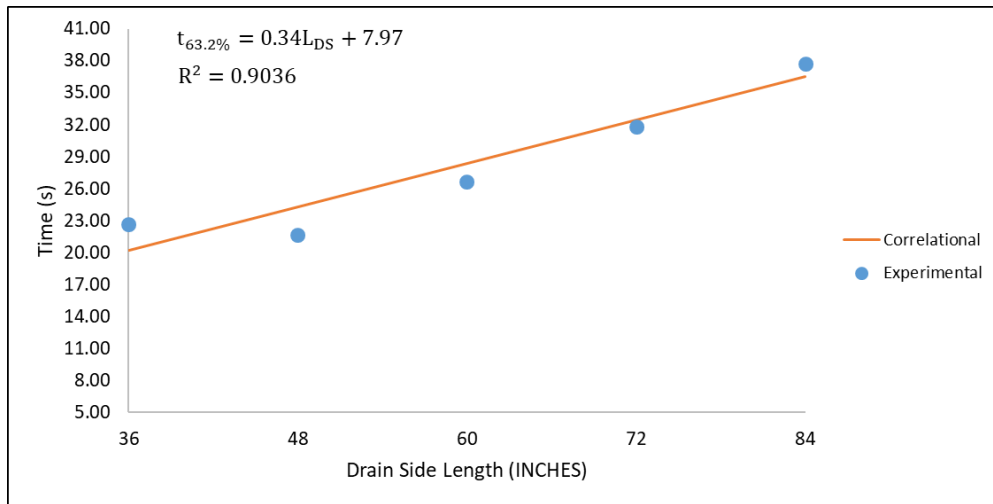


Figure B17: Experimental and correlational time response at 5.5LPM for all 3" drain-side diameter DWHR systems

Appendix C: 86.5% Response Time Data Tables and Plots

Table C1: Summarized mains-side heat transfer rate and 86.5% time responses

	14LPM			12LPM			10LPM		
	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$
R2-36	7.0634	6.1098	13.77	6.5590	5.6735	16.90	5.8895	5.0944	16.45
R2-48	9.3638	8.0996	9.04	8.7810	7.5955	11.32	7.7948	6.7425	16.55
R2-60	10.5090	9.0903	16.74	9.5071	8.2237	20.77	8.4508	7.3100	20.70
R3-36	9.2588	8.0089	16.74	8.3857	7.2536	19.54	7.5334	6.5164	20.81
R3-48	10.6157	9.1826	10.81	9.9115	8.5734	17.65	8.7781	7.5931	20.99
R3-60	12.2646	10.6089	19.19	11.3902	9.8525	20.29	9.8698	8.5374	23.68
R3-72	13.5054	11.6821	19.31	12.2686	10.6124	22.71	10.7084	9.2628	28.32
R3-84	15.7138	13.5924	20.38	13.8137	11.9488	26.51	12.2496	10.5959	31.72
R4-36	9.1926	7.9516	16.88	8.3669	7.2373	18.13	7.4888	6.4778	24.85
R4-48	12.1702	10.5272	13.57	11.0910	9.5937	15.64	9.7894	8.4678	14.94
R4-60	13.1833	11.4036	21.87	12.2273	10.5766	21.39	10.7212	9.2738	25.93
	9LPM			7LPM			5.5LPM		
	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$	$q_{\text{flow, ss}}$ (kW)	$q_{\text{flow, 86.5\%}}$ (kW)	$t_{86.5\%}$
R2-36	5.4296	4.6966	23.78	4.7779	4.1329	24.80	4.0817	3.5307	33.98
R2-48	7.3167	6.3290	12.93	6.0842	5.2628	21.01	5.2565	4.5469	34.56
R2-60	7.8195	6.7638	23.71	6.5915	5.7016	32.82	5.5835	4.8297	43.23
R3-36	6.9465	6.0087	21.87	6.1160	5.2903	31.58	5.2744	4.5624	36.80
R3-48	8.2330	7.1216	22.71	6.9507	6.0124	25.34	6.0107	5.1993	39.12
R3-60	9.3487	8.0866	26.86	7.9195	6.8504	36.52	6.7050	5.7998	44.61
R3-72	10.0905	8.7283	30.77	8.3953	7.2619	42.50	7.0852	6.1287	53.37
R3-84	11.2903	9.7661	34.93	9.2137	7.9698	39.89	7.5622	6.5413	57.25
R4-36	7.0996	6.1412	23.94	4.5884	3.9689	25.26	3.8422	3.3235	35.77
R4-48	9.2791	8.0264	19.55	7.5757	6.5529	25.26	5.9036	5.1066	29.37
R4-60	10.1566	8.7854	30.33	8.1510	7.0506	43.24	4.8278	4.1760	30.28

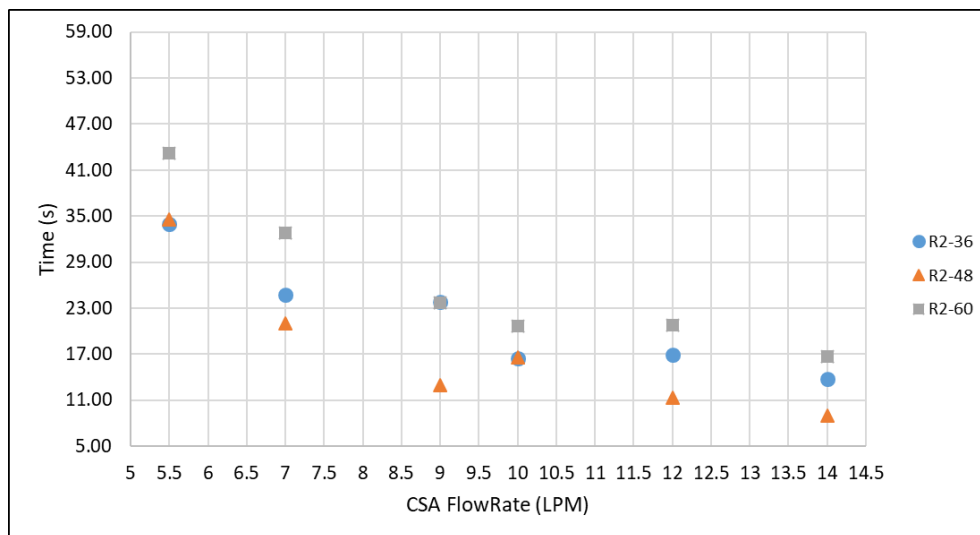


Figure C1: Experimental 86.5% time response vs flowrate of 2" drain-side diameter DWHR systems

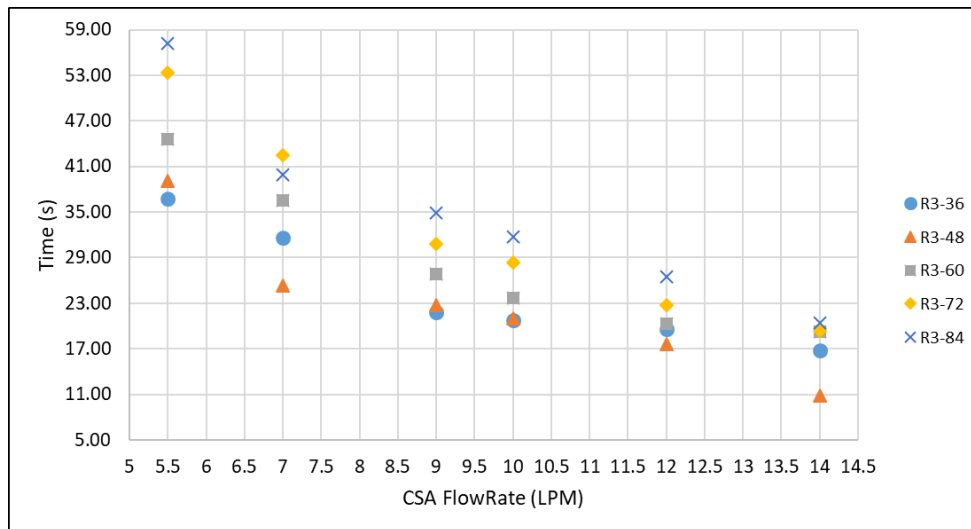


Figure C2: Experimental 86.5% time response vs flowrate of 3" drain-side diameter DWHR systems

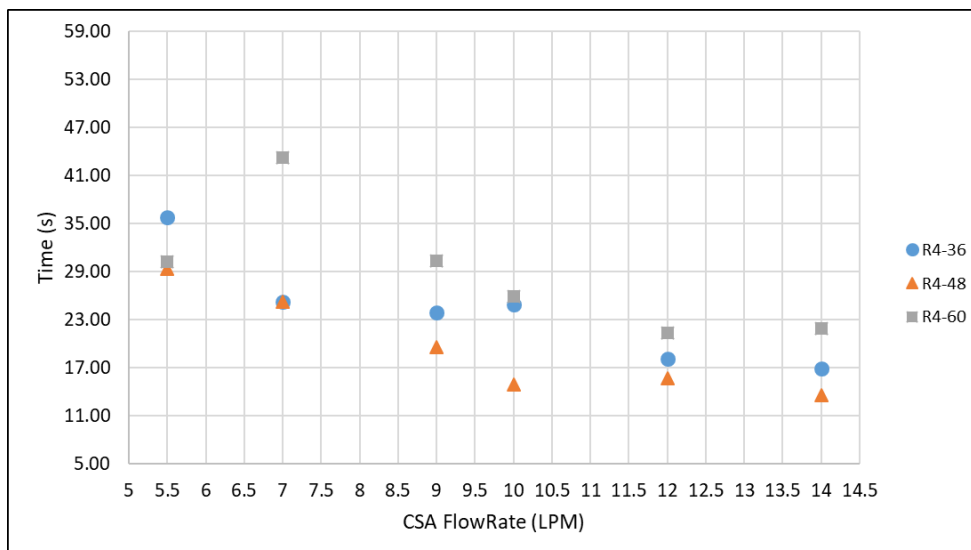


Figure C3: Experimental 86.5% time response vs flowrate of 4" drain-side diameter DWHR systems

Table C2: Correlation coefficients for all DWHR systems as a function of CSA flowrate

	A	B	R ²
	$\frac{s}{\left(\frac{L}{min}\right)}$	s	
R2-36	-2.20	42.68	0.8549
R2-48	-2.62	42.64	0.7747
R2-60	-2.89	54.06	0.8422
R3-36	-2.33	46.91	0.8729
R3-48	-2.83	49.90	0.8836
R3-60	-3.02	57.45	0.8896
R3-72	-3.94	70.55	0.924
R3-84	-3.86	72.10	0.8987
R4-36	-1.96	42.95	0.8389
R4-48	-1.88	37.76	0.8668
R4-60	-1.91	47.14	0.5533

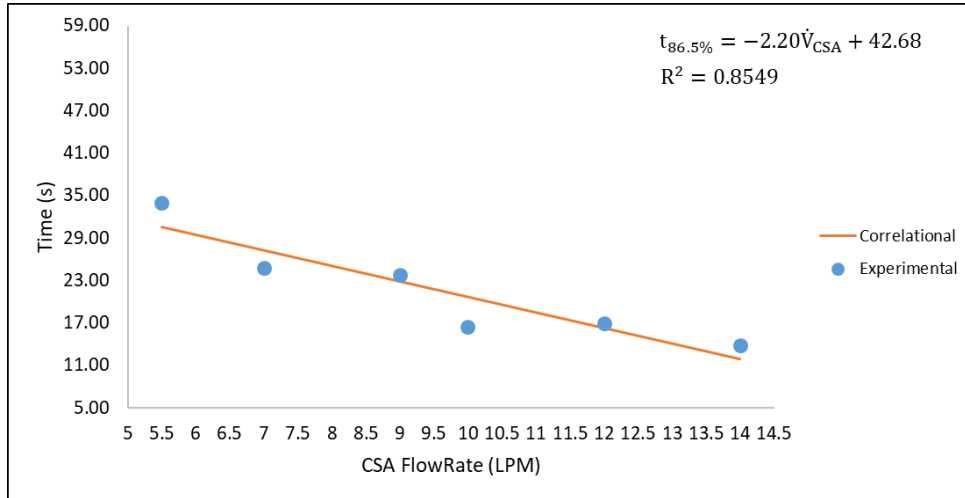


Figure C4: Experimental and correlational time response of R2-36 at different flowrates

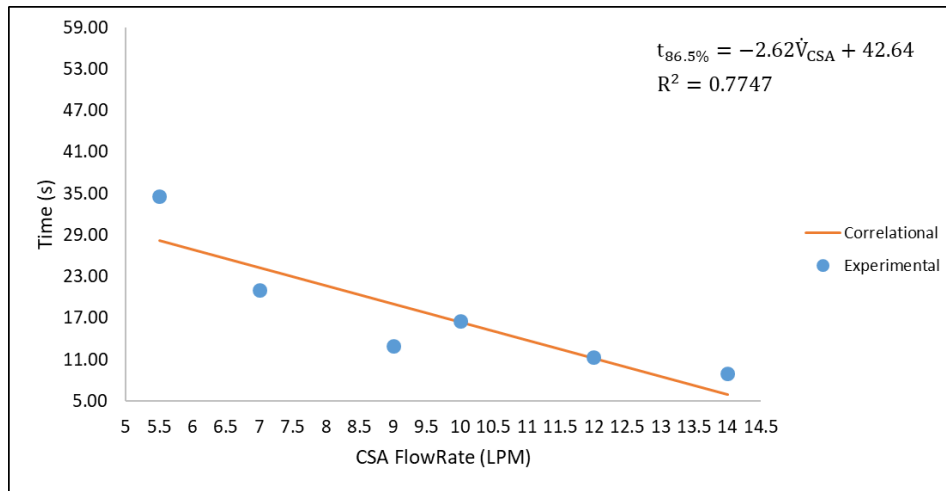


Figure C5: Experimental and correlational time response of R2-48 at different flowrates

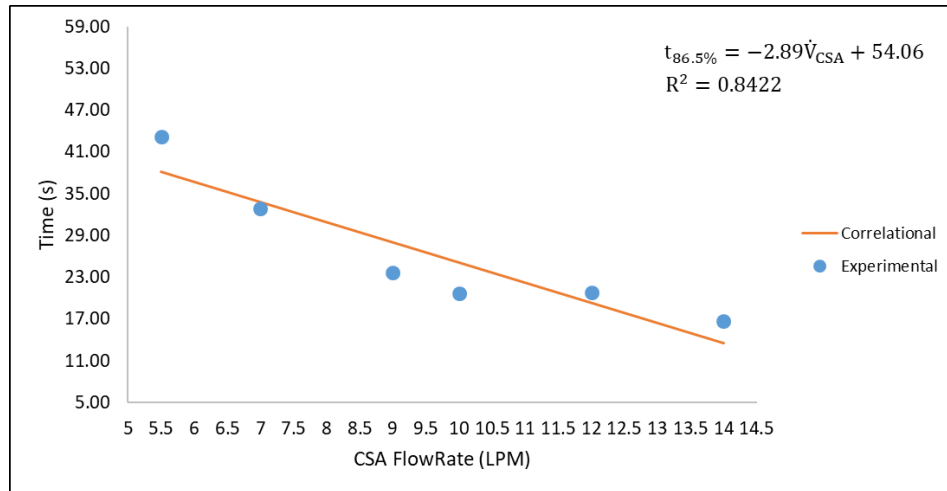


Figure C6: Experimental and correlational time response of R2-60 at different flowrates

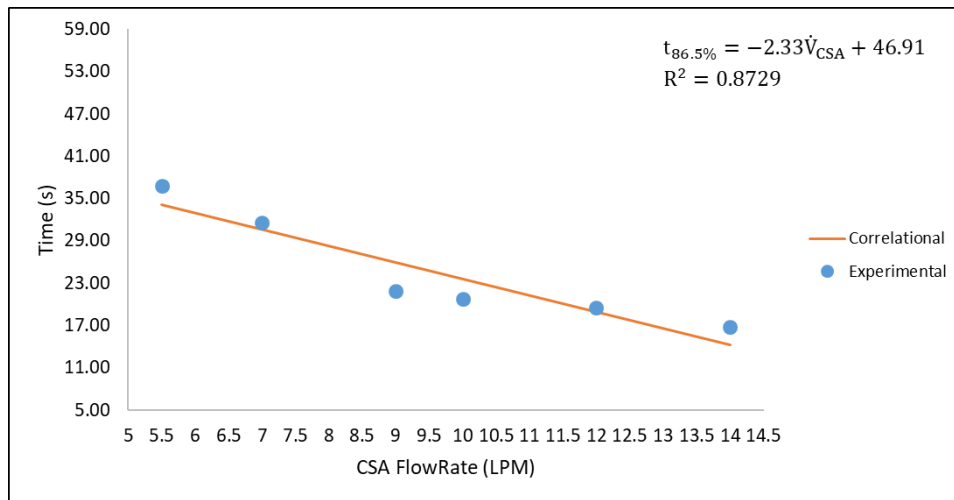


Figure C7: Experimental and correlational time response of R3-36 at different flowrates

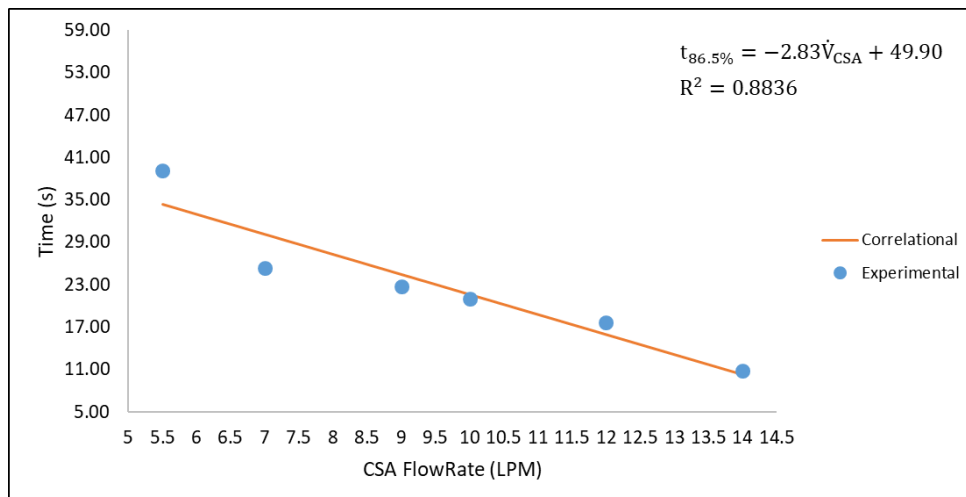


Figure C8: Experimental and correlational time response of R3-48 at different flowrates

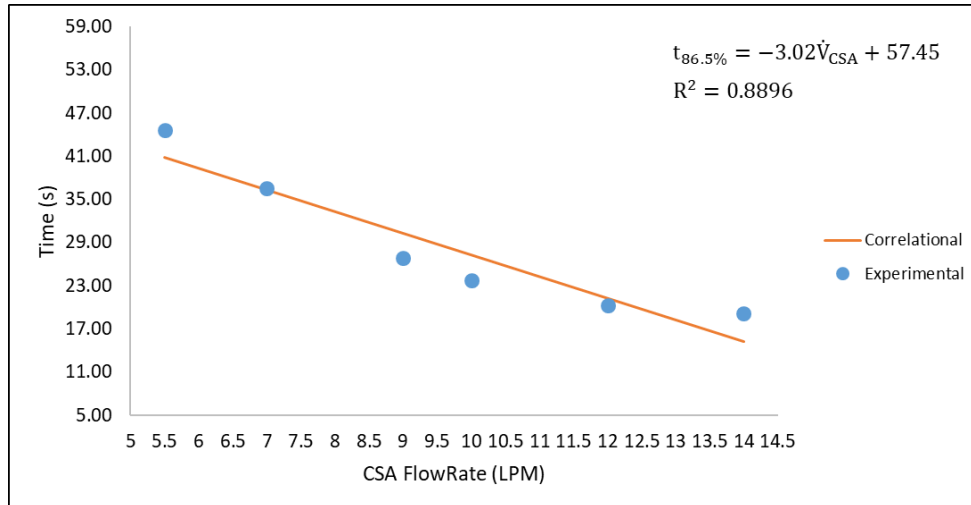


Figure C9: Experimental and correlational time response of R3-60 at different flowrates

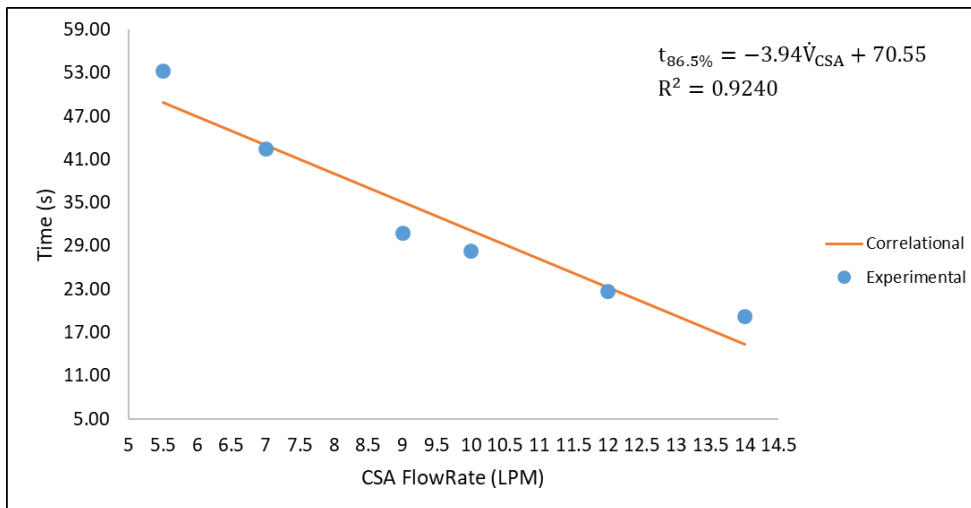


Figure C10: Experimental and correlational time response of R3-72 at different flowrates

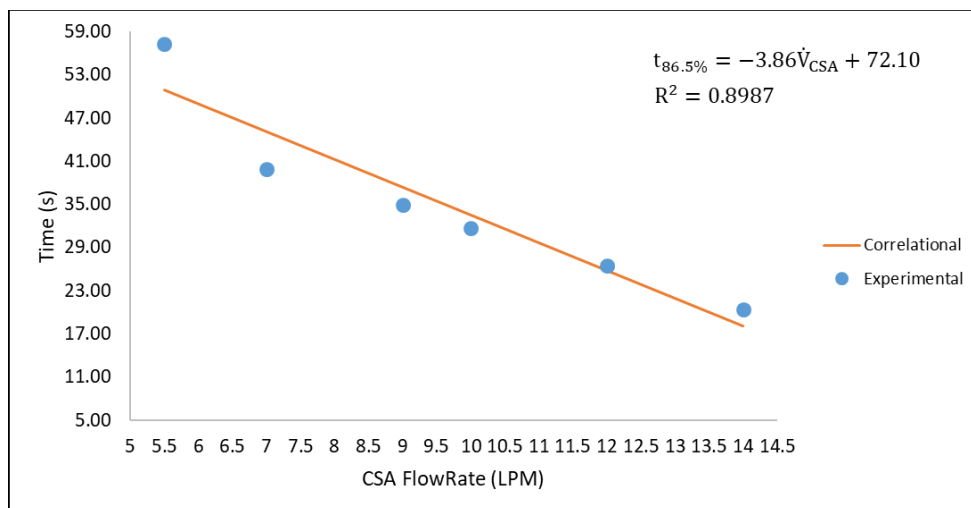


Figure C11: Experimental and correlational time response of R3-84 at different flowrates

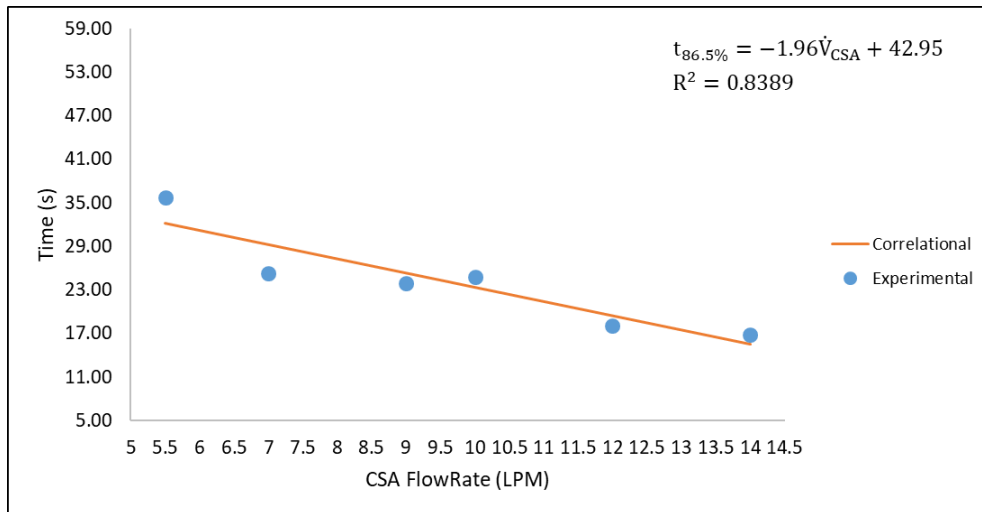


Figure C12: Experimental and correlational time response of R4-36 at different flowrates

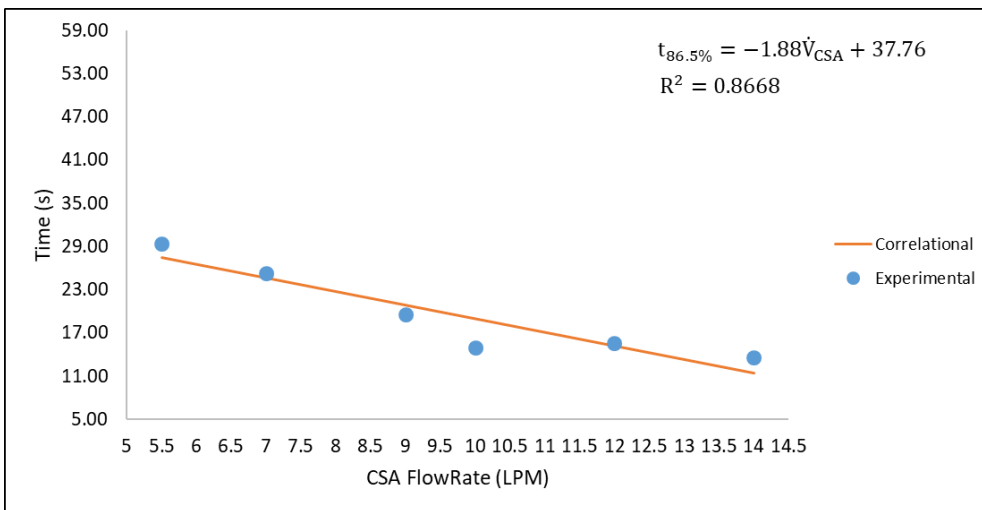


Figure C13: Experimental and correlational time response of R4-48 at different flowrates

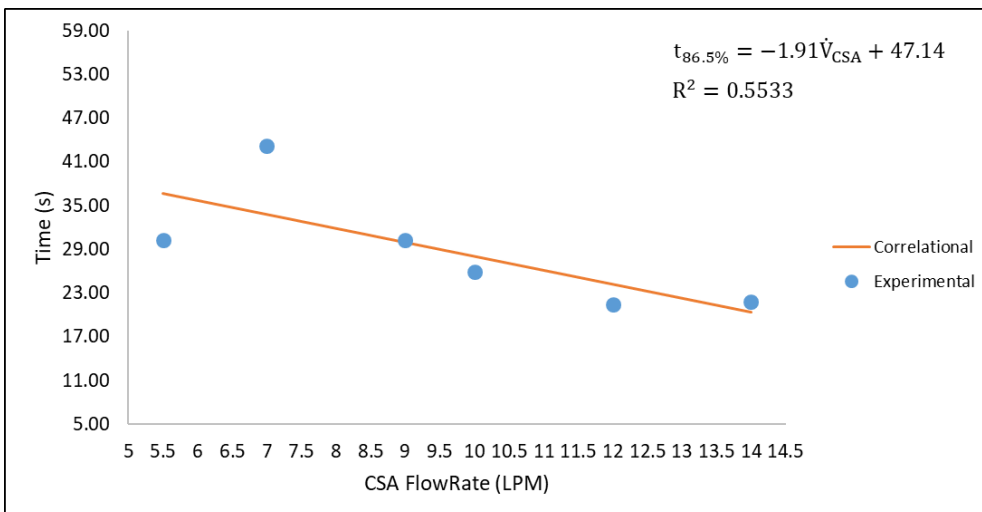


Figure C14: Experimental and correlational time response of R4-60 at different flowrates

Table C3: Difference between experimental and correlational time response all DWHR systems at CSA flowrates

Flowrate	R2-36			R2-48			R2-60			R3-72		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
14	13.77	11.88	1.89	9.04	5.96	3.08	16.74	13.60	3.14	19.31	15.39	3.92
12	16.90	16.28	0.62	11.32	11.20	0.12	20.77	19.38	1.39	22.71	23.27	-0.56
10	16.45	20.68	-4.23	16.55	16.44	0.11	20.70	25.16	-4.46	28.32	31.15	-2.83
9	23.78	22.88	0.90	12.93	19.06	-6.13	23.71	28.05	-4.34	30.77	35.09	-4.32
7	24.80	27.28	-2.48	21.01	24.30	-3.29	32.82	33.83	-1.01	42.50	42.97	-0.47
5.5	33.98	30.58	3.40	34.56	28.23	6.33	43.23	38.17	5.07	53.37	48.88	4.49
Flowrate	R3-36			R3-48			R3-60			R3-84		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
14	16.74	14.29	2.45	10.81	10.28	0.53	19.19	15.17	4.02	20.38	18.06	2.32
12	19.54	18.95	0.59	17.65	15.94	1.71	20.29	21.21	-0.92	26.51	25.78	0.73
10	20.81	23.61	-2.80	20.99	21.60	-0.61	23.68	27.25	-3.57	31.72	33.50	-1.78
9	21.87	25.94	-4.07	22.71	24.43	-1.72	26.86	30.27	-3.41	34.93	37.36	-2.43
7	31.58	30.60	0.98	25.34	30.09	-4.75	36.52	36.31	0.21	39.89	45.08	-5.19
5.5	36.80	34.10	2.71	39.12	34.34	4.79	44.61	40.84	3.77	57.25	50.87	6.38
Flowrate	R4-36			R4-48			R4-60					
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)			
14	16.88	15.51	1.36	13.57	11.44	2.13	21.87	20.40	1.47			
12	18.13	19.43	-1.30	15.64	15.20	0.44	21.39	24.22	-2.83			
10	24.85	23.35	1.50	14.94	18.96	-4.02	25.93	28.04	-2.11			
9	23.94	25.31	-1.37	19.55	20.84	-1.29	30.33	29.95	0.38			
7	25.26	29.23	-3.97	25.26	24.60	0.66	43.24	33.77	9.47			
5.5	35.77	32.17	3.60	29.37	27.42	1.95	30.28	36.64	-6.36			

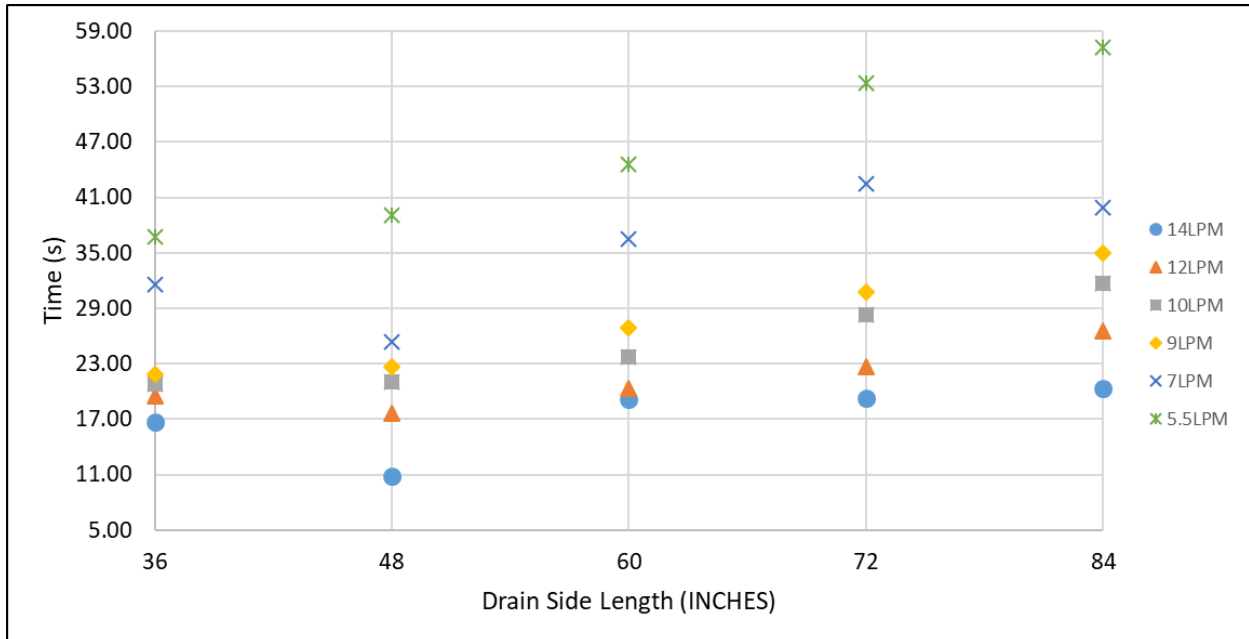


Figure C15: Experimental 86.5% time response vs drain-side length of 3" drain-side diameter DWHR systems at CSA flowrates

Table C4: Correlation coefficients for all 3" drain-side diameter DWHR systems as a function of drain-side length

	$\frac{M}{s}$ in	N s	R^2
14LPM	0.13	9.39	0.4188
12LPM	0.16	11.84	0.7751
10LPM	0.24	10.53	0.9285
9LPM	0.28	10.34	0.9661
7LPM	0.28	18.28	0.6091
5.5LPM	0.46	18.66	0.9670

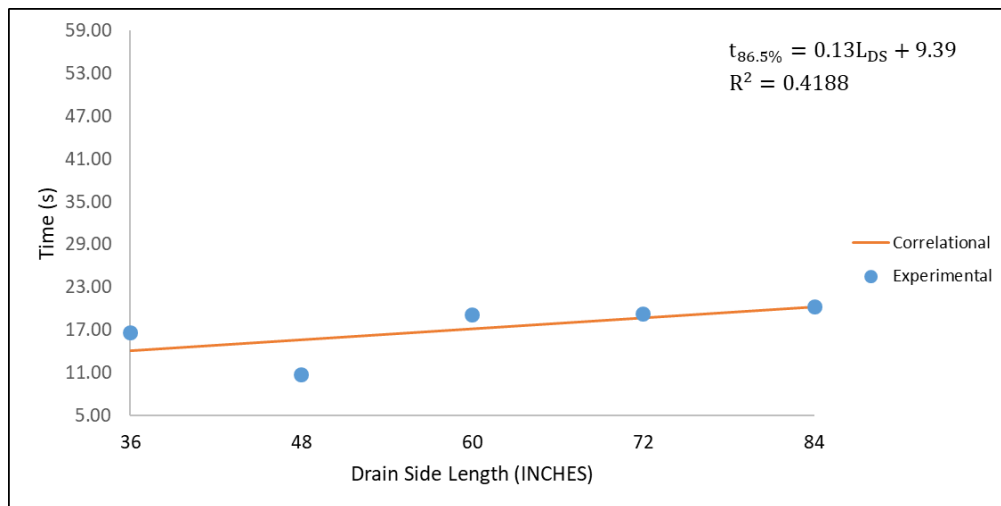


Figure C16: Experimental and correlational time response at 14LPM for all 3" drain-side diameter DWHR systems

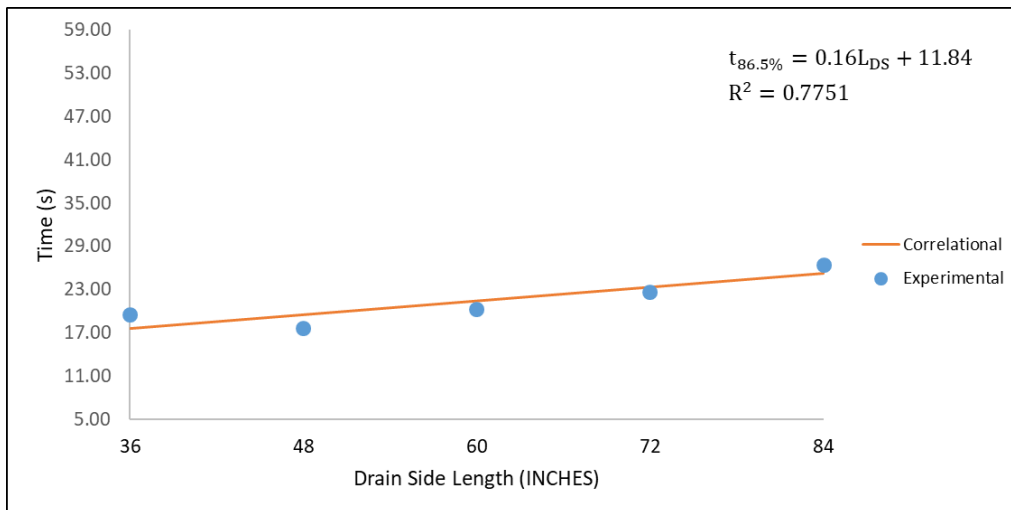


Figure C17: Experimental and correlational time response at 12LPM for all 3" drain-side diameter DWHR systems

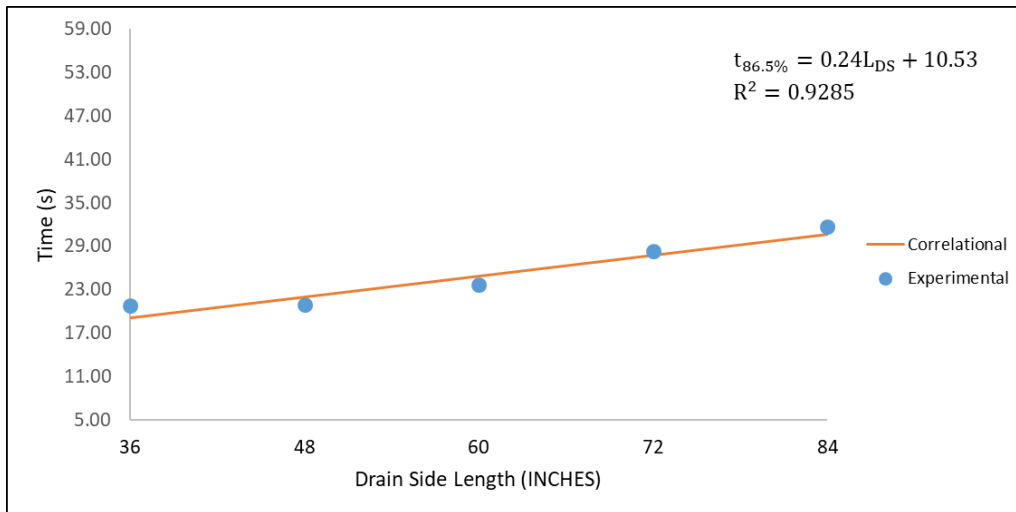


Figure C18: Experimental and correlational time response at 10LPM for all 3" drain-side diameter DWHR systems

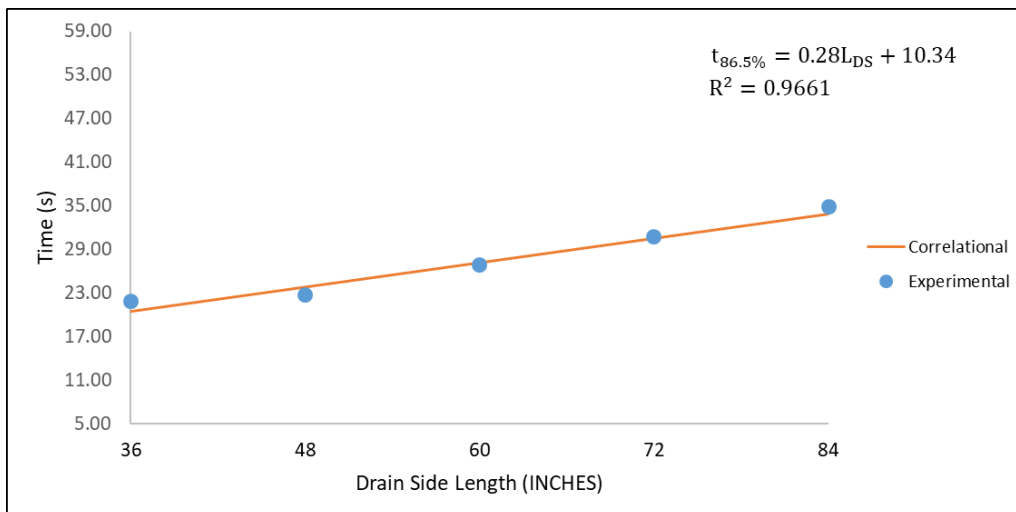


Figure C19: Experimental and correlational time response at 9LPM for all 3" drain-side diameter DWHR systems

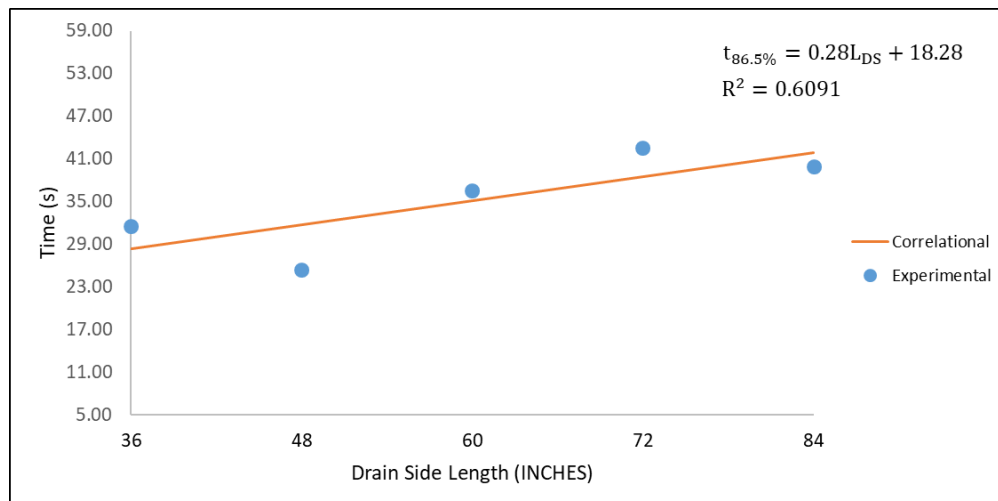


Figure C20: Experimental and correlational time response at 7LPM for all 3" drain-side diameter DWHR systems

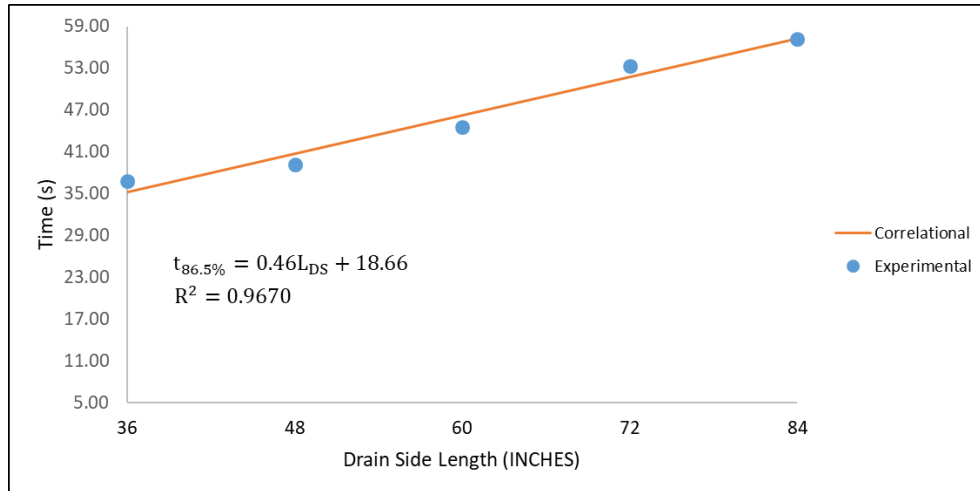


Figure C21: Experimental and correlational time response at 5.5LPM for all 3" drain-side diameter DWHR systems

Table C5: Difference between experimental and correlational time response of 3" drain-side diameter DWHR systems at CSA flowrates as a function of length

DrainSide Length	14LPM			12LPM			10LPM		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
36	16.74	14.07	2.67	19.54	17.60	1.94	20.81	19.17	1.64
48	10.81	15.63	-4.82	17.65	19.52	-1.88	20.99	22.05	-1.07
60	19.19	17.19	2.00	20.29	21.44	-1.15	23.68	24.93	-1.25
72	19.31	18.75	0.56	22.71	23.36	-0.65	28.32	27.81	0.51
84	20.38	20.31	0.07	26.51	25.28	1.23	31.72	30.69	1.03
DrainSide Length	9LPM			7LPM			5.5LPM		
	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)	Experimental (s)	Correlational (s)	Δt (s)
36	21.87	20.42	1.45	31.58	28.36	3.22	36.80	35.22	1.58
48	22.71	23.78	-1.07	25.34	31.72	-6.38	39.12	40.74	-1.62
60	26.86	27.14	-0.28	36.52	35.08	1.44	44.61	46.26	-1.65
72	30.77	30.50	0.27	42.50	38.44	4.06	53.37	51.78	1.59
84	34.93	33.86	1.07	39.89	41.80	-1.91	57.25	57.30	-0.05

Table C6: Correlation validation for different DWHR systems as a function of flowrates

	Flowrate (LPM)	Measured		Predicted	Δt (sec)	% error	$t_{99\%}$ (sec)
		q_{flow} (kW)	$t_{86.5\%}$ (sec)	$t_{86.5\%}$ (sec)			
R3-48	6.07	5.6146	38.46	32.72	5.74	14.92%	92.10
	11.35	8.3823	20.65	17.78	2.87	13.90%	57.56
R2-48	13.67	8.1961	16.55	6.82	9.73	58.79%	41.91
	9.36	6.5173	21.40	18.15	3.25	15.19%	60.33
R4-60	8.98	8.7852	89.03	29.93	59.10	66.38%	89.80
	7.96	8.0842	33.18	31.94	1.24	3.74%	99.93
R3-72	12.08	10.6912	21.94	22.95	-1.01	-4.60%	64.47
	7.55	7.6216	35.25	40.80	-5.55	-15.74%	92.10
R2-60	11.27	7.9122	20.85	21.49	-0.64	-3.07%	58.49
	9.36	6.8853	23.45	27.00	-3.55	-15.14%	68.62
R4-36	9.01	6.0319	34.04	25.29	8.75	25.71%	62.63
	7.06	5.0018	91.11	29.11	62.00	68.05%	92.10

Table C7: Correlation validation for 3" drain-side diameter DWHR systems as a function of length

	Flowrate (LPM)	Measured		Predicted	Δt (sec)	% error	$t_{99\%}$ (sec)
		q_{flow} (kW)	$t_{86.5\%}$ (sec)	$t_{86.5\%}$ (sec)			
R3-36	14	7.8177	14.43	14.07	0.36	2.49%	44.67
	12	7.3445	17.99	17.60	0.39	2.17%	52.96
	10	6.5617	22.84	19.17	3.67	16.07%	54.34
	9	6.0792	24.84	20.42	4.42	17.79%	57.56
	7	5.3755	32.62	28.36	4.26	13.06%	90.72
	5.5	4.5271	34.44	35.22	-0.78	-2.26%	105.00
R3-48	14	9.4200	15.67	15.63	0.04	0.26%	27.17
	12	8.6841	16.80	19.52	-2.72	-16.19%	43.75
	10	7.6762	18.51	22.05	-3.54	-19.12%	56.18
	9	7.1363	18.83	23.78	-4.95	-26.29%	62.17
	7	6.1433	29.46	31.72	-2.26	-7.67%	72.76
	5.5	5.1742	36.75	40.74	-3.99	-10.86%	122.04
R3-60	14	10.8905	16.91	17.19	-0.28	-1.66%	48.81
	7	6.8180	34.52	35.08	-0.56	-1.62%	108.22
R3-72	12	10.6912	21.94	23.36	-1.42	-6.47%	71.84

Appendix D: Thermocouple Calibration and Verification

Thermocouple Calibration

It is a known experience with DWHR systems that the temperature readings related to DWHR surface or water would always fall between 9°C to 40°C. Hence all the thermocouples were calibrated at the increments of 5°C between the T_{setpoint} ranges of 5°C to 45°C.

Calibration equipment consisted of a constant temperature bath connected to a container. RTDs require complete submersion in water in order to achieve an accurate reading, since they measure temperature by averaging over the entire length. The container used was large enough to ensure complete submersion of RTDs and thermocouples in water. Water was circulated from the temperature bath to the container. Sufficient mixing between the bath and the container ensured isothermal water temperature. Figure D1 shows the entire calibration equipment setup with the RTDs and thermocouples submerged in water. The transparent pipes in Figure D1 circulated the water from the bath to the container. All the thermocouples were tied together to restrict any movement in the container. Three different insertion slots were used to keep the thermocouples and RTD's apart from each other.



Figure D1: Calibration equipment set-up with RTDs and thermocouples

For each T_{setpoint} , once the RTDs and thermocouples were completely submerged in water, data acquisition was initiated exactly at the same time for both the measuring devices. Calibration equipment was run for a period of approximately 1 hour per T_{setpoint} to ensure complete isothermal conditions. The estimated temperature reading for the RTDs and thermocouples is given by Equation D1. An average was taken for the last 10 minutes, since the temperature should have been completely isothermal and at steady-state after the long duration of 50 minutes.

$$T_{\text{mean}} = \frac{\sum_n^{600} T_n}{600} \quad (\text{D.1})$$

Table D1 and Table D2 shows the samples of data acquired for two of the nine set points. T_{ci} and T_{co} refer to the temperatures recorded by RTDs. T_1 through T_{12} correspond to temperature readings for all 12 thermocouples.

Table D1: Thermocouple calibration data at $T_{setpoint} = 17^{\circ}\text{C}$

Time (s)	Date	GMT -5 hrs	$T_{ci}^{\circ}\text{C}$	$T_{co}^{\circ}\text{C}$	$T_1^{\circ}\text{C}$	$T_2^{\circ}\text{C}$	$T_3^{\circ}\text{C}$	$T_4^{\circ}\text{C}$	$T_5^{\circ}\text{C}$	$T_6^{\circ}\text{C}$	$T_7^{\circ}\text{C}$	$T_8^{\circ}\text{C}$	$T_9^{\circ}\text{C}$	$T_{10}^{\circ}\text{C}$	$T_{11}^{\circ}\text{C}$	$T_{12}^{\circ}\text{C}$
1	2018-11-09	11:44:51 AM	17.89	17.85	17.40	17.40	17.38	17.35	17.30	17.25	17.23	17.12	17.06	17.14	17.17	17.21
2	2018-11-09	11:44:52 AM	17.88	17.85	17.40	17.40	17.38	17.35	17.30	17.24	17.23	17.12	17.06	17.14	17.17	17.21
3	2018-11-09	11:44:53 AM	17.88	17.85	17.40	17.41	17.39	17.36	17.32	17.25	17.23	17.12	17.07	17.14	17.18	17.21
4	2018-11-09	11:44:54 AM	17.88	17.85	17.40	17.41	17.39	17.36	17.32	17.26	17.23	17.13	17.08	17.15	17.19	17.23
5	2018-11-09	11:44:55 AM	17.88	17.85	17.40	17.40	17.38	17.35	17.29	17.24	17.23	17.13	17.05	17.14	17.18	17.20
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
3598	2018-11-09	12:44:48 PM	17.88	17.85	17.51	17.52	17.49	17.45	17.39	17.31	17.29	17.18	17.13	17.22	17.27	17.29
3599	2018-11-09	12:44:49 PM	17.88	17.85	17.51	17.52	17.48	17.45	17.40	17.32	17.29	17.18	17.14	17.22	17.27	17.30
3600	2018-11-09	12:44:50 PM	17.88	17.85	17.51	17.52	17.50	17.44	17.38	17.31	17.28	17.17	17.13	17.22	17.26	17.30
3601	2018-11-09	12:44:51 PM	17.88	17.85	17.51	17.51	17.48	17.45	17.38	17.32	17.29	17.17	17.13	17.21	17.26	17.29
Mean last 10 minutes			17.88	17.85	17.52	17.52	17.48	17.45	17.38	17.31	17.28	17.17	17.12	17.21	17.25	17.29

Table D2: Thermocouple calibration data at $T_{setpoint} = 41^{\circ}\text{C}$

Time (s)	Date	GMT -5 hrs	$T_{ci}^{\circ}\text{C}$	$T_{co}^{\circ}\text{C}$	$T_1^{\circ}\text{C}$	$T_2^{\circ}\text{C}$	$T_3^{\circ}\text{C}$	$T_4^{\circ}\text{C}$	$T_5^{\circ}\text{C}$	$T_6^{\circ}\text{C}$	$T_7^{\circ}\text{C}$	$T_8^{\circ}\text{C}$	$T_9^{\circ}\text{C}$	$T_{10}^{\circ}\text{C}$	$T_{11}^{\circ}\text{C}$	$T_{12}^{\circ}\text{C}$
1	2018-11-12	3:33:52 PM	41.96	41.92	40.98	41.01	40.99	40.96	40.91	40.86	40.82	40.74	40.74	40.83	40.87	40.93
2	2018-11-12	3:33:53 PM	41.96	41.92	40.98	41.01	40.98	40.96	40.92	40.86	40.83	40.74	40.75	40.83	40.88	40.92
3	2018-11-12	3:33:54 PM	41.96	41.92	40.98	40.99	40.97	40.96	40.91	40.85	40.82	40.73	40.75	40.82	40.87	40.90
4	2018-11-12	3:33:55 PM	41.96	41.92	40.98	41.00	40.98	40.96	40.91	40.85	40.82	40.74	40.74	40.83	40.87	40.91
5	2018-11-12	3:33:56 PM	41.96	41.92	40.98	41.00	40.97	40.95	40.91	40.85	40.83	40.74	40.73	40.83	40.88	40.92
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
3598	2018-11-12	4:33:49 PM	41.92	41.89	40.85	40.87	40.87	40.86	40.83	40.78	40.78	40.71	40.73	40.81	40.88	40.94
3599	2018-11-12	4:33:50 PM	41.92	41.89	40.86	40.87	40.87	40.86	40.83	40.79	40.78	40.70	40.72	40.81	40.88	40.94
3600	2018-11-12	4:33:51 PM	41.92	41.89	40.85	40.87	40.86	40.85	40.83	40.79	40.78	40.70	40.72	40.80	40.88	40.93
3601	2018-11-12	4:33:52 PM	41.92	41.89	40.84	40.87	40.86	40.85	40.83	40.79	40.78	40.70	40.73	40.79	40.87	40.93
Mean last 10 minutes			41.92	41.89	40.86	40.88	40.87	40.86	40.84	40.79	40.78	40.71	40.71	40.81	40.87	40.92

Table D3 shows the summarized and condensed version of all of the calibration data collected. RTD 1 and RTD 2 represents T_{ci} and T_{co} .

Table D3: Summary of thermocouple calibration data

T _{setpoint} (°C)	RTD 1 (°C)	RTD 2 (°C)	RTD mean (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T ₉ (°C)	T ₁₀ (°C)	T ₁₁ (°C)	T ₁₂ (°C)
5	5.63	5.60	5.61	5.48	5.48	5.45	5.43	5.37	5.31	5.28	5.17	5.12	5.21	5.26	5.32
9	9.80	9.76	9.78	9.58	9.59	9.55	9.52	9.47	9.40	9.37	9.25	9.21	9.30	9.35	9.40
13	13.83	13.79	13.81	13.68	13.67	13.62	13.58	13.50	13.42	13.40	13.27	13.26	13.37	13.43	13.47
17	17.88	17.85	17.87	17.52	17.52	17.48	17.45	17.38	17.31	17.28	17.17	17.12	17.21	17.25	17.29
21	21.98	21.94	21.96	21.56	21.56	21.53	21.50	21.42	21.35	21.33	21.21	21.20	21.30	21.36	21.40
25	26.05	26.01	26.03	25.52	25.53	25.50	25.47	25.40	25.33	25.31	25.20	25.18	25.28	25.34	25.38
29	30.14	30.10	30.12	29.42	29.43	29.41	29.40	29.36	29.30	29.27	29.17	29.12	29.21	29.24	29.28
33	33.82	33.78	33.80	33.18	33.18	33.14	33.10	33.03	32.96	32.93	32.81	32.76	32.85	32.90	32.93
37	37.96	37.93	37.94	37.03	37.03	37.01	36.99	36.95	36.89	36.87	36.79	36.79	36.88	36.94	36.98
41	41.92	41.89	41.90	40.86	40.88	40.87	40.86	40.84	40.79	40.78	40.71	40.71	40.81	40.87	40.92
45	45.87	45.84	45.86	44.84	44.86	44.85	44.83	44.79	44.73	44.70	44.61	44.59	44.69	44.74	44.78

Since both the RTD's readings were almost identical, an average was taken to derive a single calibration reference temperature. It is displayed in RTD mean column in Table D3. All twelve thermocouples were calibrated through comparison with RTD mean. It could be noted that the rows showing T_{mean} for last 10 minutes in Table D1 and Table D2 corresponded to the rows for T_{setpoint} of 17°C and 41°C respectively in Table D3.

The last step in completing calibration was to input the summarized thermocouple calibration data from Table D3 into the LabVIEW calibration wizard. Figure D2 shows the calibration wizard for thermocouple 6.

Channel Calibration Wizard

Edit calibration measurement values.

1. Navigate to the row to be edited by clicking on it or using the arrow keys. To enter a new calibration value, navigate to the bottom row.
2. Enter the reference value of the measurement on the row indicated by the arrow.
3. Setup your signal to take a measurement at the specified reference value. Wait for the reading shown in the Uncalibrated column to stabilize.
4. Click "Commit Calibration Value" or press the Enter key.

Reference	Uncalibrated	Difference
0.0000	0.0000	0.0000
5.6100	5.3100	0.3000
9.7800	9.4000	0.3800
13.8100	13.4200	0.3900
17.8700	17.3100	0.5600
21.9600	21.3500	0.6100
26.0300	25.3300	0.7000
30.1200	29.3000	0.8200
33.8000	32.9600	0.8400

Commit Calibration Value

Units: Deg C

< Back Next > Finish Cancel

Figure D2: Channel calibration wizard for Thermocouple 6

“Reference” and “Uncalibrated” columns in Figure D2 corresponded to “RTD mean” and “T6” columns in Table D3. The same process was used to input calibration data for all twelve thermocouples by clicking back and next button. Calibration was completed at the end by clicking “Finish”.

This calibration is only valid for thermocouple temperature readings between 5°C and 45°C. Hence if in the future any tests are to be conducted outside the specified range, further calibration would be required to ensure accuracy.

Thermocouple Calibration Verification

Calibration verification was completed by gathering data for both the thermocouples and RTDs at random temperatures to ensure similarity. Once it was determined that the RTDs and thermocouples were providing very similar temperature outputs, it was concluded that the thermocouples could be used for experiments related to DWHR surface temperature estimation. Table D4 and Table D5 represent the RTD/thermocouple data collection and difference between the two readings respectively.

Table D4: RTD and thermocouple data collection for calibration verification

Date	GMT -5 hrs	T _d °C	T _{co} °C	Tmean (°C)	T ₁ °C	T ₂ °C	T ₃ °C	T ₄ °C	T ₅ °C	T ₆ °C	T ₇ °C	T ₈ °C	T ₉ °C	T ₁₀ °C	T ₁₁ °C	T ₁₂ °C
2018-11-14	2:04:00 PM	14.04	14.01	14.03	13.89	13.91	13.91	13.95	14.00	14.01	14.07	14.07	14.00	14.07	14.09	14.17
2018-11-14	2:04:01 PM	14.04	14.01	14.03	13.89	13.91	13.91	13.95	14.00	14.02	14.05	14.07	14.01	14.06	14.07	14.16
2018-11-14	2:04:02 PM	14.04	14.01	14.03	13.87	13.89	13.90	13.95	13.97	14.02	14.03	14.06	14.01	14.06	14.06	14.15
2018-11-14	2:04:03 PM	14.04	14.01	14.03	13.85	13.89	13.91	13.96	13.98	14.02	14.03	14.07	14.02	14.08	14.07	14.16
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2018-11-14	3:39:38 PM	36.73	36.74	36.74	36.46	36.63	36.51	36.41	36.49	36.78	36.55	36.55	36.75	36.59	36.65	36.58
2018-11-14	3:39:39 PM	36.73	36.75	36.74	36.51	36.64	36.49	36.43	36.48	36.77	36.53	36.54	36.79	36.60	36.64	36.66
2018-11-14	3:39:40 PM	36.74	36.75	36.75	36.54	36.48	36.59	36.43	36.48	36.71	36.59	36.54	36.79	36.64	36.63	36.77

Table D5: RTD and thermocouple data collection for calibration verification – temperature differences

Date	GMT -5 hrs	ΔT ₁ °C	ΔT ₂ °C	ΔT ₃ °C	ΔT ₄ °C	ΔT ₅ °C	ΔT ₆ °C	ΔT ₇ °C	ΔT ₈ °C	ΔT ₉ °C	ΔT ₁₀ °C	ΔT ₁₁ °C	ΔT ₁₂ °C
2018-11-14	2:04:00 PM	0.14	0.12	0.11	0.08	0.03	0.01	-0.04	-0.05	0.03	-0.05	-0.06	-0.14
2018-11-14	2:04:01 PM	0.14	0.12	0.11	0.07	0.02	0.01	-0.03	-0.04	0.01	-0.04	-0.05	-0.13
2018-11-14	2:04:02 PM	0.16	0.14	0.13	0.08	0.06	0.01	-0.01	-0.04	0.01	-0.04	-0.04	-0.12
2018-11-14	2:04:03 PM	0.18	0.13	0.12	0.07	0.04	0.00	-0.01	-0.04	0.01	-0.06	-0.05	-0.13
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2018-11-14	3:39:38 PM	0.27	0.10	0.22	0.32	0.25	-0.04	0.18	0.19	-0.01	0.14	0.08	0.15
2018-11-14	3:39:39 PM	0.22	0.09	0.24	0.30	0.26	-0.04	0.20	0.20	-0.05	0.13	0.10	0.07
2018-11-14	3:39:40 PM	0.19	0.26	0.14	0.31	0.25	0.02	0.14	0.19	-0.06	0.10	0.10	-0.04
Minimum ΔT		0.09	0.07	0.05	0.00	-0.05	-0.11	-0.16	-0.14	-0.13	-0.17	-0.27	-0.35
Maximum ΔT		0.36	0.44	0.36	0.47	0.37	0.27	0.41	0.31	0.36	0.40	0.44	0.41

Data collection in Table D4 is similar to Table D1 and Table D2, where the columns display RTD and thermocouple temperature readings. Table D5 shows the difference between RTD mean and thermocouple temperature. It was observed that the min and max temperature difference ranged from -0.35°C to 0.47°C of RTDs. Hence the calibration error of the thermocouples was about $\pm 0.5^{\circ}\text{C}$. This deviation was not significant since any calibration will still induce minor measurement errors. At this point, it was concluded that the thermocouples were correctly calibrated and could be used for experimentation.

Appendix E: Raw Data Tables at Selected Time Instants

Table E1: Raw RTD and thermocouple data sample for R3-36 at 14LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-05	10:50:04 AM	1	22.51	22.7	23.05	22.4	9.18	22.36	22.40	22.42	22.42	22.46	22.43	22.44	22.46	22.50	22.45
2018-12-05	10:50:05 AM	2	22.49	22.66	23.09	22.43	11.91	22.33	22.36	22.39	22.40	22.43	22.41	22.41	22.43	22.48	22.42
2018-12-05	10:50:06 AM	3	22.47	22.65	23.04	22.47	13.8	22.26	22.32	22.33	22.39	22.45	22.41	22.43	22.46	22.50	22.44
2018-12-05	10:50:08 AM	5	20.99	22.63	24.88	22.58	13.85	21.14	21.06	21.14	21.67	22.01	22.33	22.41	22.48	22.50	22.44
2018-12-05	10:50:11 AM	8	17.74	22.58	30.65	22.7	13.81	18.83	18.71	18.77	19.59	20.12	20.98	21.53	21.93	22.36	22.25
2018-12-05	10:50:13 AM	10	16.43	22.3	32.84	22.85	13.86	17.42	17.44	17.49	18.50	19.14	20.12	21.05	21.64	22.14	21.85
2018-12-05	10:50:18 AM	15	13.75	21.54	36.07	25.47	13.74	14.73	15.35	15.37	16.87	17.77	19.01	20.71	21.62	21.88	21.24
2018-12-05	10:50:23 AM	20	12.18	21.11	37.13	27.49	14.16	13.09	14.13	14.09	15.75	16.79	18.15	20.19	21.24	21.65	20.77
2018-12-05	10:50:33 AM	30	10.79	20.03	37.69	28.47	14.23	11.47	12.89	12.85	14.60	15.72	17.11	19.40	20.55	21.00	19.77
2018-12-05	10:50:53 AM	50	10	19.35	37.99	28.5	14.08	10.39	12.16	12.16	13.96	15.13	16.50	18.94	20.14	20.56	19.15
2018-12-05	10:51:43 AM	100	9.63	19.13	38.21	28.57	14.08	9.80	11.86	11.80	13.67	14.92	16.33	18.83	20.04	20.43	18.92
2018-12-05	10:53:23 AM	200	9.51	19.06	38.28	28.58	14.05	9.65	11.70	11.70	13.54	14.78	16.19	18.75	20.01	20.41	18.86

Table E2: Raw RTD and thermocouple data sample for R3-36 at 12LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-06	10:31:42 AM	1	22.47	22.65	23.17	22.5	9.65	22.33	22.40	22.42	22.42	22.45	22.45	22.45	22.49	22.53	22.46
2018-12-06	10:31:43 AM	2	22.46	22.64	23.12	22.52	11.66	22.31	22.38	22.41	22.42	22.45	22.44	22.46	22.49	22.53	22.46
2018-12-06	10:31:44 AM	3	22.43	22.64	23.11	22.54	11.79	22.29	22.36	22.39	22.41	22.46	22.43	22.46	22.49	22.53	22.45
2018-12-06	10:31:46 AM	5	21.08	22.63	25.11	22.63	11.82	21.63	21.60	21.79	22.14	22.34	22.44	22.49	22.53	22.54	22.46
2018-12-06	10:31:49 AM	8	19.69	22.65	27.93	22.72	11.88	19.85	19.72	19.99	20.65	21.04	21.71	22.08	22.38	22.55	22.46
2018-12-06	10:31:51 AM	10	17.76	22.59	31.47	22.77	11.9	18.60	18.52	18.82	19.67	20.17	21.03	21.69	22.18	22.51	22.28
2018-12-06	10:31:56 AM	15	14.67	22.09	35.68	24.78	11.97	16.02	16.46	16.67	18.02	18.83	19.95	21.41	22.23	22.49	21.89
2018-12-06	10:32:01 AM	20	13.35	22	36.65	26.67	12	14.23	15.25	15.36	17.01	18.03	19.34	21.23	22.26	22.59	21.76
2018-12-06	10:32:11 AM	30	11.81	21.36	37.4	27.94	12	12.42	13.89	13.97	15.80	16.94	18.33	20.53	21.71	22.35	21.01
2018-12-06	10:32:31 AM	50	10.74	20.46	37.8	28	12.03	11.12	12.97	13.02	14.91	16.10	17.54	19.92	21.16	21.81	20.25
2018-12-06	10:33:21 AM	100	10.28	20.1	38.06	28.08	12.09	10.43	12.58	12.59	14.51	15.77	17.22	19.68	20.98	21.59	19.92
2018-12-06	10:35:01 AM	200	10.14	20.06	38.17	28.13	12.09	10.28	12.46	12.47	14.43	15.70	17.15	19.69	21.00	21.60	19.87

Table E3: Raw RTD and thermocouple data sample for R3-36 at 10LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-06	5:10:40 PM	1	22.44	22.88	23.29	23.14	9.84	22.35	22.46	22.47	22.53	22.60	22.61	22.66	22.70	22.72	22.73
2018-12-06	5:10:41 PM	2	22.37	22.88	23.31	23.13	9.86	22.27	22.39	22.42	22.49	22.56	22.58	22.63	22.66	22.71	22.71
2018-12-06	5:10:42 PM	3	22.29	22.88	23.33	23.12	9.88	22.03	22.16	22.26	22.44	22.55	22.57	22.63	22.66	22.71	22.70
2018-12-06	5:10:44 PM	5	21.46	22.86	24.42	23.07	9.87	21.14	21.23	21.43	21.88	22.16	22.39	22.55	22.61	22.66	22.66
2018-12-06	5:10:47 PM	8	19.09	22.8	29.3	22.99	9.98	19.50	19.58	19.81	20.56	21.00	21.58	22.14	22.44	22.61	22.58
2018-12-06	5:10:49 PM	10	17.51	22.7	31.71	22.94	9.97	18.46	18.67	18.85	19.77	20.34	21.07	21.95	22.43	22.59	22.45
2018-12-06	5:10:54 PM	15	15.12	22.44	35.04	24.2	9.95	16.18	16.85	17.00	18.39	19.23	20.26	21.78	22.59	22.78	22.24
2018-12-06	5:10:59 PM	20	13.56	22.41	36.41	25.89	9.98	14.55	15.70	15.82	17.52	18.56	19.82	21.74	22.79	23.07	22.22
2018-12-06	5:11:09 PM	30	11.99	22.13	37.19	27.08	10.02	12.69	14.29	14.39	16.34	17.55	18.93	21.20	22.43	22.94	21.82
2018-12-06	5:11:29 PM	50	10.78	21.25	37.7	27.18	9.98	11.24	13.20	13.32	15.34	16.63	18.09	20.54	21.85	22.45	21.06
2018-12-06	5:12:19 PM	100	10.14	20.82	38.03	27.2	10.01	10.37	12.64	12.74	14.84	16.18	17.70	20.24	21.60	22.21	20.66
2018-12-06	5:13:59 PM	200	9.95	20.74	38.17	27.22	10.04	10.16	12.46	12.54	14.63	15.98	17.53	20.13	21.55	22.17	20.60

Table E4: Raw RTD and thermocouple data sample for R3-36 at 9LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-07	10:29:36 AM	1	21.66	22.68	23.68	22.64	8.83	21.96	21.95	22.08	22.23	22.35	22.39	22.44	22.47	22.50	22.49
2018-12-07	10:29:37 AM	2	21.22	22.68	24.65	22.66	8.87	21.68	21.60	21.80	22.07	22.25	22.35	22.42	22.46	22.51	22.49
2018-12-07	10:29:38 AM	3	20.97	22.68	25.19	22.68	8.90	21.31	21.15	21.42	21.79	22.04	22.26	22.38	22.44	22.49	22.48
2018-12-07	10:29:40 AM	5	19.65	22.66	27.29	22.73	8.96	20.45	20.15	20.49	21.05	21.43	21.89	22.23	22.41	22.48	22.46
2018-12-07	10:29:43 AM	8	18.14	22.62	30.45	22.72	9.04	19.05	18.89	19.19	20.01	20.54	21.21	21.95	22.35	22.52	22.36
2018-12-07	10:29:45 AM	10	16.82	22.52	32.72	22.86	9.06	18.17	18.15	18.42	19.41	20.04	20.84	21.83	22.36	22.56	22.25
2018-12-07	10:29:50 AM	15	14.84	22.39	35.45	23.93	9.06	16.25	16.79	16.98	18.44	19.32	20.40	21.98	22.81	23.06	22.26
2018-12-07	10:29:55 AM	20	13.51	22.61	36.42	25.67	9.01	14.79	15.77	15.95	17.74	18.83	20.11	22.06	23.10	23.47	22.44
2018-12-07	10:30:05 AM	30	12.01	22.47	37.18	26.74	9.03	13.00	14.52	14.68	16.69	17.92	19.34	21.62	22.88	23.41	22.19
2018-12-07	10:30:25 AM	50	10.91	21.74	37.66	26.76	9.11	11.49	13.39	13.59	15.69	17.01	18.52	20.98	22.36	22.97	21.49
2018-12-07	10:31:15 AM	100	10.27	21.32	38.02	26.77	9.1	10.53	12.85	12.94	15.14	16.56	18.09	20.70	22.13	22.77	21.10
2018-12-07	10:32:55 AM	200	10.07	21.28	38.16	26.8	9.07	10.29	12.70	12.84	15.05	16.47	18.05	20.69	22.15	22.80	21.07

Table E5: Raw RTD and thermocouple data sample for R3-36 at 7LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-07	5:14:25 PM	1	21.89	22.95	23.59	22.99	6.76	22.07	22.17	22.29	22.49	22.59	22.64	22.72	22.76	22.81	22.76
2018-12-07	5:14:26 PM	2	21.59	22.94	24.03	22.97	6.73	21.86	21.94	22.11	22.37	22.53	22.60	22.70	22.74	22.79	22.76
2018-12-07	5:14:27 PM	3	21.22	22.93	24.66	22.96	6.76	21.63	21.64	21.86	22.21	22.42	22.57	22.67	22.71	22.77	22.74
2018-12-07	5:14:29 PM	5	20.06	22.89	27.41	22.93	6.79	21.02	20.97	21.27	21.77	22.08	22.40	22.61	22.71	22.76	22.71
2018-12-07	5:14:32 PM	8	18.88	22.86	30	22.85	6.84	19.99	19.89	20.26	21.01	21.47	22.00	22.54	22.80	22.81	22.68
2018-12-07	5:14:34 PM	10	18.15	22.85	31.07	22.79	6.84	19.28	19.31	19.67	20.58	21.13	21.81	22.58	22.98	22.94	22.69
2018-12-07	5:14:39 PM	15	16.26	22.95	34.01	23.13	6.97	17.63	18.10	18.43	19.77	20.55	21.50	22.84	23.54	23.45	22.86
2018-12-07	5:14:44 PM	20	14.82	23.25	35.44	24.1	7	16.21	17.21	17.50	19.17	20.18	21.33	23.13	24.05	24.06	23.16
2018-12-07	5:14:54 PM	30	13	23.61	36.68	25.19	7.02	14.16	15.89	16.13	18.24	19.40	20.84	23.05	24.27	24.65	23.38
2018-12-07	5:15:14 PM	50	11.47	23.28	37.41	25.54	7.07	12.18	14.47	14.74	17.12	18.43	20.05	22.57	23.98	24.61	23.02
2018-12-07	5:16:04 PM	100	10.44	22.77	37.9	25.34	7	10.78	13.65	13.85	16.36	17.82	19.48	22.19	23.70	24.40	22.57
2018-12-07	5:17:44 PM	200	10.13	22.69	38.1	25.36	7.01	10.39	13.40	13.57	16.13	17.65	19.36	22.11	23.66	24.45	22.48

Table E6: Raw RTD and thermocouple data sample for R3-36 at 5.5LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _d (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _d (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-08	12:22:35 PM	1	22.05	22.81	23.61	22.78	4.99	22.12	22.22	22.37	22.48	22.56	22.57	22.60	22.63	22.66	22.63
2018-12-08	12:22:36 PM	2	21.85	22.81	23.84	22.79	5.01	21.98	22.09	22.26	22.43	22.53	22.56	22.59	22.65	22.67	22.63
2018-12-08	12:22:37 PM	3	21.36	22.82	24.46	22.82	5.03	21.77	21.88	22.12	22.35	22.48	22.54	22.58	22.64	22.67	22.63
2018-12-08	12:22:39 PM	5	20.83	22.82	25.35	22.83	5.04	21.35	21.42	21.76	22.12	22.35	22.49	22.59	22.65	22.70	22.65
2018-12-08	12:22:42 PM	8	19.94	22.84	27.24	22.84	5.09	20.58	20.58	21.07	21.57	21.91	22.27	22.53	22.68	22.73	22.68
2018-12-08	12:22:44 PM	10	19.03	22.88	29.03	22.86	5.16	20.03	20.01	20.52	21.14	21.56	22.05	22.45	22.71	22.78	22.73
2018-12-08	12:22:49 PM	15	17.54	23.02	31.74	23.15	5.39	18.61	18.52	19.16	19.97	20.59	21.41	22.20	22.78	22.99	22.90
2018-12-08	12:22:54 PM	20	16.24	23.22	33.51	23.74	5.48	17.30	17.88	18.28	19.64	20.53	21.51	22.90	23.79	23.91	23.16
2018-12-08	12:23:04 PM	30	14.17	23.92	35.96	24.06	5.65	15.08	16.60	17.10	18.91	20.02	21.36	23.34	24.56	25.05	23.81
2018-12-08	12:23:24 PM	50	12.03	24.41	37.1	24.72	5.58	12.66	14.91	15.46	17.79	19.12	20.84	23.29	24.86	25.74	24.17
2018-12-08	12:24:14 PM	100	10.58	23.87	37.79	24.27	5.54	10.82	13.73	14.19	16.74	18.24	20.05	22.75	24.48	25.53	23.62
2018-12-08	12:25:54 PM	200	10.1	23.7	38.05	24.25	5.6	10.27	13.34	13.79	16.39	17.92	19.76	22.58	24.38	25.50	23.46

Table E7: Raw RTD and thermocouple data sample for R3-60 at 14LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-08	6:07:32 PM	1	22.04	23.03	23.53	22.71	11.91	21.87	21.97	22.17	22.43	22.56	22.59	22.69	22.86	23.03	22.93
2018-12-08	6:07:33 PM	2	21.9	23.06	23.6	22.83	12.96	21.80	21.93	22.09	22.30	22.50	22.60	22.67	22.81	22.97	22.91
2018-12-08	6:07:34 PM	3	21.58	23.05	23.81	22.88	13.65	21.42	21.51	22.00	22.24	22.42	22.54	22.67	22.80	22.92	22.89
2018-12-08	6:07:36 PM	5	19.94	22.99	25.96	22.95	13.69	19.87	19.79	20.71	21.62	22.14	22.39	22.58	22.73	22.84	22.82
2018-12-08	6:07:39 PM	8	17.01	22.92	32.03	22.84	13.68	17.63	17.51	18.50	19.75	20.67	21.50	22.30	22.79	23.10	22.82
2018-12-08	6:07:41 PM	10	15.85	23.01	33.71	22.78	13.65	16.34	16.33	17.34	18.77	19.83	20.89	21.96	22.90	23.57	23.06
2018-12-08	6:07:46 PM	15	13.47	23.56	36.13	24.04	13.55	13.92	14.35	15.32	17.21	18.53	19.92	21.30	22.99	24.15	23.52
2018-12-08	6:07:51 PM	20	12.11	23.69	37.01	25.05	14.49	12.51	13.14	14.04	16.11	17.53	19.10	20.64	22.65	23.98	23.44
2018-12-08	6:08:01 PM	30	10.92	23.23	37.61	25.56	14.35	11.20	12.09	12.93	15.09	16.60	18.22	19.78	22.10	23.55	22.91
2018-12-08	6:08:21 PM	50	10.21	22.81	37.97	25.28	13.9	10.43	11.54	12.38	14.62	16.13	17.84	19.41	21.94	23.51	22.64
2018-12-08	6:09:11 PM	100	9.87	22.73	38.22	25.22	13.84	9.99	11.20	12.07	14.34	15.88	17.62	19.19	21.84	23.42	22.55
2018-12-08	6:10:51 PM	200	9.75	22.68	38.29	25.25	13.93	9.79	11.07	11.91	14.17	15.75	17.54	19.12	21.82	23.45	22.46

Table E8: Raw RTD and thermocouple data sample for R3-60 at 12LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-09	2:44:14 PM	1	22.51	22.99	23.32	22.66	11.52	22.19	22.27	22.52	22.64	22.73	22.74	22.77	22.82	22.88	22.78
2018-12-09	2:44:15 PM	2	22.34	22.98	23.51	22.71	11.7	21.69	21.70	22.32	22.59	22.69	22.73	22.77	22.84	22.90	22.80
2018-12-09	2:44:16 PM	3	21.15	22.98	25.3	22.81	11.67	21.09	21.02	21.84	22.40	22.62	22.69	22.76	22.84	22.91	22.79
2018-12-09	2:44:18 PM	5	19.79	22.99	26.54	22.88	11.77	19.73	19.61	20.56	21.60	22.04	22.46	22.71	22.88	23.02	22.83
2018-12-09	2:44:21 PM	8	17.32	23.08	31.84	22.84	11.84	17.78	17.72	18.71	20.06	20.82	21.64	22.43	23.04	23.42	23.00
2018-12-09	2:44:23 PM	10	15.8	23.32	34.11	22.82	11.93	16.64	16.69	17.68	19.25	20.18	21.19	22.19	23.27	23.96	23.25
2018-12-09	2:44:28 PM	15	14.05	23.96	35.93	23.79	12.01	14.46	14.94	15.94	17.97	19.22	20.59	21.86	23.72	24.91	23.98
2018-12-09	2:44:33 PM	20	12.76	24.47	36.9	24.79	12.04	13.14	13.90	14.87	17.12	18.52	20.09	21.56	23.74	25.15	24.26
2018-12-09	2:44:43 PM	30	11.47	24.29	37.5	25.1	12.18	11.76	12.75	13.64	16.03	17.51	19.19	20.77	23.22	24.80	23.89
2018-12-09	2:45:03 PM	50	10.67	23.74	37.85	24.75	11.98	10.84	12.00	12.87	15.25	16.83	18.59	20.17	22.82	24.51	23.43
2018-12-09	2:45:53 PM	100	10.25	23.56	38.13	24.65	12.04	10.32	11.59	12.50	14.92	16.54	18.36	19.93	22.71	24.47	23.29
2018-12-09	2:47:33 PM	200	10.11	23.56	38.22	24.68	12.1	10.12	11.45	12.35	14.74	16.39	18.22	19.83	22.63	24.43	23.26

Table E9: Raw RTD and thermocouple data sample for R3-60 at 10LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-09	7:14:20 PM	1	22.14	23.17	23.46	22.91	9.85	22.04	22.18	22.42	22.64	22.77	22.83	22.88	22.97	23.06	22.97
2018-12-09	7:14:21 PM	2	21.83	23.17	23.6	22.97	9.91	21.70	21.81	22.30	22.58	22.71	22.79	22.86	22.96	23.05	22.96
2018-12-09	7:14:22 PM	3	21.36	23.16	23.99	22.99	9.92	21.24	21.32	22.01	22.49	22.66	22.75	22.85	22.96	23.04	22.96
2018-12-09	7:14:24 PM	5	20.21	23.15	25.86	23.01	9.94	20.14	20.15	21.08	21.99	22.35	22.60	22.78	22.91	23.02	22.93
2018-12-09	7:14:27 PM	8	18.43	23.13	29.41	22.96	9.9	18.44	18.44	19.46	20.81	21.46	22.12	22.64	23.08	23.38	23.00
2018-12-09	7:14:29 PM	10	16.88	23.2	32.06	22.83	9.91	17.37	17.45	18.48	20.03	20.84	21.73	22.49	23.31	23.87	23.25
2018-12-09	7:14:34 PM	15	14.58	23.91	35.14	23.18	9.99	15.19	15.59	16.67	18.65	19.82	21.10	22.25	23.85	24.97	24.01
2018-12-09	7:14:39 PM	20	13.32	24.5	36.1	23.8	9.93	13.66	14.36	15.43	17.70	19.11	20.64	22.02	24.08	25.52	24.56
2018-12-09	7:14:49 PM	30	11.57	24.97	37.23	24.2	9.97	12.02	12.98	14.00	16.46	18.05	19.77	21.46	23.87	25.62	24.72
2018-12-09	7:15:09 PM	50	10.47	24.48	37.73	23.83	9.92	10.79	11.97	12.94	15.46	17.16	19.04	20.71	23.41	25.34	24.24
2018-12-09	7:15:59 PM	100	9.84	24.19	38.12	23.62	9.92	10.03	11.33	12.33	14.86	16.61	18.56	20.28	23.14	25.22	24.00
2018-12-09	7:17:39 PM	200	9.67	24.17	38.25	23.61	9.98	9.79	11.19	12.18	14.71	16.53	18.48	20.21	23.13	25.19	23.97

Table E10: Raw RTD and thermocouple data sample for R3-60 at 9LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _{cl} (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _{cl} (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-10	10:38:56 AM	1	21.81	22.75	23.79	22.64	8.81	21.80	21.91	22.36	22.53	22.59	22.60	22.61	22.67	22.73	22.57
2018-12-10	10:38:57 AM	2	21.32	22.76	24.58	22.66	8.83	21.39	21.46	22.12	22.48	22.58	22.60	22.61	22.68	22.75	22.65
2018-12-10	10:38:58 AM	3	20.82	22.77	25.37	22.68	8.85	20.92	20.96	21.76	22.35	22.53	22.59	22.62	22.70	22.78	22.59
2018-12-10	10:39:00 AM	5	19.73	22.79	26.38	22.7	8.93	19.91	19.92	20.87	21.84	22.20	22.50	22.62	22.77	22.92	22.65
2018-12-10	10:39:03 AM	8	17.76	22.89	30.83	22.67	8.92	18.44	18.41	19.45	20.81	21.42	22.09	22.58	23.02	23.34	22.81
2018-12-10	10:39:05 AM	10	16.48	23.1	33.22	22.55	8.9	17.50	17.58	18.62	20.14	20.90	21.77	22.45	23.21	23.78	23.04
2018-12-10	10:39:10 AM	15	14.84	23.77	35.09	22.68	8.94	15.51	15.92	17.04	18.99	20.12	21.38	22.37	23.99	25.16	23.96
2018-12-10	10:39:15 AM	20	13.48	24.67	36.19	23.47	8.99	14.09	14.78	15.89	18.19	19.54	21.06	22.35	24.40	25.88	24.65
2018-12-10	10:39:25 AM	30	11.91	25.37	37.03	23.92	9.03	12.38	13.37	14.47	17.01	18.62	20.37	21.97	24.44	26.23	25.14
2018-12-10	10:39:45 AM	50	10.75	25.01	37.56	23.46	8.99	11.05	12.28	13.31	15.90	17.66	19.51	21.19	23.93	25.93	24.72
2018-12-10	10:40:35 AM	100	10.08	24.71	37.96	23.13	9.02	10.23	11.61	12.64	15.23	17.07	19.07	20.79	23.66	25.80	24.49
2018-12-10	10:42:15 AM	200	9.86	24.69	38.12	23.12	8.95	9.92	11.42	12.46	15.11	16.96	18.96	20.70	23.69	25.85	24.45

Table E11: Raw RTD and thermocouple data sample for R3-60 at 7LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _{cl} (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _{cl} (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-10	4:18:29 PM	1	22.15	22.6	22.88	22.37	6.93	22.12	22.20	22.27	22.35	22.42	22.43	22.44	22.45	22.51	22.51
2018-12-10	4:18:30 PM	2	22.06	22.59	22.9	22.39	6.95	22.00	22.10	22.25	22.31	22.39	22.40	22.42	22.45	22.50	22.51
2018-12-10	4:18:31 PM	3	21.62	22.6	23.33	22.42	7	21.82	21.92	22.21	22.31	22.39	22.40	22.42	22.47	22.51	22.50
2018-12-10	4:18:33 PM	5	21.3	22.6	23.78	22.43	7.02	21.24	21.30	21.93	22.26	22.36	22.37	22.41	22.47	22.51	22.51
2018-12-10	4:18:36 PM	8	19.7	22.62	27.29	22.44	7.13	20.17	20.16	21.07	21.84	22.15	22.33	22.41	22.50	22.61	22.54
2018-12-10	4:18:38 PM	10	18.93	22.63	28.33	22.43	7.14	19.41	19.40	20.39	21.44	21.88	22.25	22.45	22.66	22.87	22.61
2018-12-10	4:18:43 PM	15	16.5	23.02	33	22.25	7.05	17.58	17.68	18.81	20.33	21.18	22.01	22.60	23.47	24.11	23.17
2018-12-10	4:18:48 PM	20	15.21	23.77	34.32	22.31	7.09	16.02	16.40	17.61	19.55	20.72	21.92	22.88	24.40	25.48	24.15
2018-12-10	4:18:58 PM	30	13.03	25.61	36.09	22.9	7.19	13.81	14.60	15.93	18.37	19.90	21.56	23.07	25.27	26.84	25.64
2018-12-10	4:19:18 PM	50	11.42	26.26	37.28	22.59	7.14	11.94	13.09	14.41	17.18	18.94	20.90	22.67	25.35	27.27	26.13
2018-12-10	4:20:08 PM	100	10.43	26.06	37.85	22.02	7.13	10.75	12.10	13.42	16.24	18.17	20.23	22.15	25.05	27.19	25.93
2018-12-10	4:21:48 PM	200	10.12	26.09	38.06	21.91	7.12	10.34	11.85	13.14	16.01	18.00	20.10	22.08	25.08	27.29	25.96

Table E12: Raw RTD and thermocouple data sample for R3-60 at 5.5LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _{cl} (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _{cl} (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-11	11:40:44 AM	1	21.09	21.49	22.27	21.46	5.22	21.16	21.21	21.38	21.41	21.46	21.43	21.42	21.42	21.44	21.47
2018-12-11	11:40:45 AM	2	20.93	21.49	22.56	21.46	5.21	21.05	21.09	21.35	21.42	21.46	21.44	21.43	21.43	21.45	21.48
2018-12-11	11:40:46 AM	3	20.54	21.5	23.58	21.46	5.23	20.89	20.94	21.29	21.41	21.46	21.44	21.44	21.44	21.47	21.49
2018-12-11	11:40:48 AM	5	20.08	21.52	25.14	21.47	5.21	20.50	20.50	21.08	21.35	21.45	21.44	21.45	21.46	21.50	21.49
2018-12-11	11:40:51 AM	8	19.19	21.55	27.68	21.47	5.25	19.83	19.76	20.55	21.12	21.36	21.45	21.49	21.54	21.65	21.54
2018-12-11	11:40:53 AM	10	18.54	21.6	29.19	21.45	5.25	19.33	19.24	20.14	20.92	21.27	21.47	21.57	21.72	21.92	21.65
2018-12-11	11:40:58 AM	15	17.08	22	31.62	21.4	5.34	18.11	18.12	19.18	20.38	21.05	21.65	21.98	22.66	23.30	22.24
2018-12-11	11:41:03 AM	20	15.71	23.07	33.22	21.47	5.37	16.97	17.11	18.33	19.90	20.87	21.83	22.55	23.72	24.75	23.25
2018-12-11	11:41:13 AM	30	14.15	24.97	35.12	21.74	5.37	15.11	15.63	17.04	19.15	20.54	21.99	23.33	25.14	26.71	25.16
2018-12-11	11:41:33 AM	50	12.34	26.94	36.78	21.77	5.51	12.98	13.88	15.41	18.01	19.78	21.70	23.69	26.15	28.23	26.90
2018-12-11	11:42:23 AM	100	10.97	27.22	37.78	21.21	5.64	11.35	12.60	14.15	16.95	18.93	21.07	23.36	26.18	28.44	27.14
2018-12-11	11:44:03 AM	200	10.56	27.36	38.08	21.03	5.57	10.81	12.19	13.75	16.59	18.68	20.86	23.28	26.18	28.60	27.23

Table E13: Raw RTD and thermocouple data sample for 4-36 at 14LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T ₉ (°C)
2018-12-12	10:31:16 AM	1	22.26	22.32	22.52	21.8	9.17	22.14	22.21	22.22	22.19	22.21	22.15	22.12	22.11	22.14	22.12
2018-12-12	10:31:17 AM	2	22.28	22.3	22.7	21.85	11.88	22.13	22.20	22.21	22.20	22.19	22.14	22.12	22.13	22.14	22.10
2018-12-12	10:31:18 AM	3	22.26	22.28	22.76	22	13.47	21.92	22.10	22.14	22.21	22.22	22.16	22.14	22.14	22.17	22.12
2018-12-12	10:31:20 AM	5	21.12	22.29	23.42	22.12	13.68	20.37	20.62	20.75	21.67	22.11	22.20	22.19	22.20	22.22	22.15
2018-12-12	10:31:23 AM	8	18.57	22.32	27.34	22.34	13.74	17.94	18.03	18.36	19.47	20.41	21.30	21.90	22.28	22.40	22.27
2018-12-12	10:31:25 AM	10	17.04	22.38	30.72	22.48	13.82	16.55	16.60	17.15	18.24	19.25	20.57	21.47	22.18	22.49	22.25
2018-12-12	10:31:30 AM	15	13.74	22	35.66	25.56	13.79	14.04	14.24	15.33	16.34	17.35	19.12	20.41	21.46	22.14	21.55
2018-12-12	10:31:35 AM	20	12.28	21.26	36.88	27.88	13.84	12.65	12.95	14.35	15.35	16.30	18.35	19.79	20.96	21.79	20.90
2018-12-12	10:31:45 AM	30	11.01	20.13	37.55	28.89	14.13	11.27	11.72	13.24	14.12	15.00	17.11	18.69	20.04	20.96	19.83
2018-12-12	10:32:05 AM	50	10.16	19	37.92	28.98	14.27	10.34	10.91	12.52	13.38	14.29	16.50	18.14	19.45	20.36	18.93
2018-12-12	10:32:55 AM	100	9.8	18.83	38.15	28.99	13.93	9.81	10.53	12.26	13.14	14.06	16.34	18.00	19.36	20.30	18.76
2018-12-12	10:34:35 AM	200	9.69	18.83	38.24	28.99	13.88	9.68	10.42	12.21	13.11	13.98	16.29	18.02	19.41	20.34	18.75

Table E14: Raw RTD and thermocouple data sample for 4-36 at 12LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T ₉ (°C)
2018-12-12	5:51:19 PM	1	22.36	22.57	23.1	22.81	11.75	21.83	22.09	22.17	22.32	22.40	22.42	22.46	22.52	22.59	22.38
2018-12-12	5:51:20 PM	2	21.61	22.58	23.75	22.8	11.8	21.28	21.57	21.68	22.22	22.39	22.44	22.48	22.53	22.62	22.40
2018-12-12	5:51:21 PM	3	20.98	22.59	24.81	22.8	11.81	20.64	20.92	21.07	21.85	22.29	22.42	22.48	22.53	22.61	22.40
2018-12-12	5:51:23 PM	5	18.92	22.61	28.62	22.83	11.8	19.30	19.51	19.77	20.79	21.59	22.16	22.51	22.66	22.73	22.45
2018-12-12	5:51:26 PM	8	16.6	22.77	33.16	23.32	11.81	17.45	17.61	18.12	19.16	20.18	21.38	22.24	22.84	23.05	22.64
2018-12-12	5:51:28 PM	10	15.69	22.84	34.53	24.11	11.93	16.37	16.54	17.35	18.37	19.41	20.90	21.99	22.80	23.15	22.63
2018-12-12	5:51:33 PM	15	14	22.61	36.06	26.07	11.95	14.34	14.63	15.82	16.84	17.92	19.80	21.22	22.37	23.13	22.27
2018-12-12	5:51:38 PM	20	12.57	22.04	37.02	27.99	12.04	13.07	13.46	14.91	15.92	16.97	19.08	20.63	21.96	22.85	21.75
2018-12-12	5:51:48 PM	30	11.48	21.12	37.53	28.49	11.95	11.75	12.31	14.08	15.06	16.03	18.39	19.99	21.31	22.19	20.83
2018-12-12	5:52:08 PM	50	10.66	20.13	37.87	28.35	12	10.80	11.53	13.53	14.55	15.51	17.94	19.53	20.85	21.69	20.01
2018-12-12	5:52:58 PM	100	10.26	19.84	38.14	28.41	11.98	10.36	11.11	13.06	14.06	15.03	17.51	19.21	20.61	21.47	19.80
2018-12-12	5:54:38 PM	200	10.13	19.73	38.25	28.61	12.08	10.13	10.90	12.72	13.67	14.66	16.99	18.71	20.19	21.34	19.62

Table E15: Raw RTD and thermocouple data sample for 4-36 at 10LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _{hi} (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T ₉ (°C)
2018-12-13	10:51:20 AM	1	22.41	22.41	23.01	22.22	9.57	22.19	22.31	22.31	22.31	22.34	22.28	22.26	22.26	22.28	22.18
2018-12-13	10:51:21 AM	2	22.39	22.41	22.98	22.24	9.61	22.21	22.29	22.30	22.32	22.35	22.32	22.29	22.29	22.31	22.20
2018-12-13	10:51:22 AM	3	22.37	22.41	22.98	22.26	9.67	21.95	22.17	22.23	22.30	22.36	22.33	22.32	22.32	22.34	22.23
2018-12-13	10:51:24 AM	5	21.34	22.45	24.22	22.36	9.76	21.13	21.44	21.57	22.11	22.34	22.37	22.37	22.38	22.41	22.29
2018-12-13	10:51:27 AM	8	19.04	22.53	27.3	22.6	9.83	19.50	19.72	20.02	20.98	21.71	22.14	22.38	22.50	22.54	22.38
2018-12-13	10:51:29 AM	10	18.02	22.59	29.92	22.68	9.84	18.48	18.58	19.00	20.02	20.94	21.74	22.32	22.64	22.70	22.46
2018-12-13	10:51:34 AM	15	15.53	22.77	34.82	23.53	9.98	16.16	16.35	17.40	18.39	19.46	21.03	22.18	23.03	23.28	22.59
2018-12-13	10:51:39 AM	20	13.88	22.8	36.14	26.01	10.04	14.49	14.85	16.37	17.43	18.56	20.53	21.99	23.11	23.67	22.62
2018-12-13	10:51:49 AM	30	12.29	22.43	37.1	27.55	10.01	12.63	13.16	15.08	16.14	17.27	19.57	21.20	22.53	23.39	22.09
2018-12-13	10:52:09 AM	50	11.05	21.32	37.65	27.48	9.96	11.23	11.96	14.00	15.09	16.26	18.72	20.43	21.82	22.74	21.13
2018-12-13	10:52:59 AM	100	10.43	20.79	38	27.43	9.99	10.49	11.34	13.53	14.62	15.71	18.28	20.02	21.47	22.46	20.70
2018-12-13	10:54:39 AM	200	10.26	20.74	38.14	27.5	10	10.31	11.20	13.45	14.52	15.63	18.30	20.08	21.51	22.45	20.69

Table E16: Raw RTD and thermocouple data sample for 4-36 at 9LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-13	5:40:19 PM	1	22.33	22.58	23.18	22.94	8.9	22.08	22.25	22.30	22.29	22.34	22.37	22.42	22.50	22.58	22.38
2018-12-13	5:40:20 PM	2	22.12	22.59	23.2	22.93	8.93	21.90	22.11	22.19	22.30	22.35	22.37	22.43	22.50	22.58	22.42
2018-12-13	5:40:21 PM	3	21.3	22.61	23.8	22.92	9.01	21.55	21.81	21.92	22.25	22.35	22.37	22.41	22.49	22.59	22.41
2018-12-13	5:40:23 PM	5	20.52	22.62	24.93	22.93	9.06	20.67	20.90	21.08	21.84	22.23	22.36	22.41	22.50	22.59	22.43
2018-12-13	5:40:26 PM	8	18.67	22.62	28.67	22.95	9.1	19.11	19.27	19.53	20.56	21.38	21.93	22.31	22.54	22.65	22.46
2018-12-13	5:40:28 PM	10	17.74	22.64	30.69	23.06	9.1	18.17	18.25	18.53	19.61	20.56	21.35	22.02	22.53	22.74	22.53
2018-12-13	5:40:33 PM	15	15.2	22.77	34.72	24.91	9.19	16.03	16.10	16.41	17.50	18.52	19.73	20.97	22.12	22.87	22.55
2018-12-13	5:40:38 PM	20	13.94	22.56	35.86	26.73	9.14	14.57	14.53	14.91	15.91	16.97	18.43	19.95	21.54	22.74	22.21
2018-12-13	5:40:48 PM	30	12.18	21.48	37.01	28.64	9.21	12.66	12.80	13.47	14.32	15.45	17.73	19.50	21.29	22.43	21.21
2018-12-13	5:41:08 PM	50	11.03	21.69	37.56	26.86	9.09	11.30	12.01	14.03	15.20	16.47	18.99	20.74	22.22	23.26	21.58
2018-12-13	5:41:58 PM	100	10.35	21.28	37.94	26.81	9.06	10.43	11.31	13.51	14.67	15.91	18.57	20.39	21.95	23.03	21.19
2018-12-13	5:43:38 PM	200	10.16	21.28	38.09	26.79	9.04	10.20	11.13	13.38	14.55	15.78	18.49	20.36	21.97	23.10	21.19

Table E17: Raw RTD and thermocouple data sample for 4-36 at 7LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-14	10:23:29 AM	1	22.35	22.36	23.02	22.3	6.53	22.27	22.36	22.38	22.37	22.36	22.31	22.29	22.29	22.33	22.14
2018-12-14	10:23:30 AM	2	22.35	22.37	23.03	22.31	6.54	22.24	22.34	22.37	22.38	22.38	22.34	22.30	22.31	22.34	22.15
2018-12-14	10:23:31 AM	3	22.34	22.37	23.1	22.34	6.61	22.16	22.29	22.35	22.37	22.40	22.36	22.32	22.32	22.35	22.17
2018-12-14	10:23:33 AM	5	21.63	22.41	24.14	22.46	6.65	21.80	22.01	22.12	22.34	22.39	22.39	22.36	22.38	22.40	22.20
2018-12-14	10:23:36 AM	8	20.17	22.47	27.23	22.63	6.76	20.92	21.13	21.31	21.96	22.30	22.39	22.40	22.44	22.47	22.26
2018-12-14	10:23:38 AM	10	19.6	22.5	28.18	22.69	6.83	20.23	20.38	20.61	21.47	22.03	22.32	22.43	22.51	22.55	22.33
2018-12-14	10:23:43 AM	15	17.35	22.79	32.35	23.6	6.92	18.46	18.45	18.75	19.80	20.74	21.56	22.21	22.71	22.95	22.65
2018-12-14	10:23:48 AM	20	15.74	23.14	34.68	25.38	6.96	16.87	16.78	17.11	18.16	19.21	20.35	21.48	22.58	23.30	22.94
2018-12-14	10:23:58 AM	30	13.8	22.89	36.43	28.12	7.05	14.53	14.45	14.76	15.71	16.78	18.23	19.80	21.60	23.16	22.58
2018-12-14	10:24:18 AM	50	11.99	21.13	37.33	29.06	7.03	12.35	12.39	12.67	13.41	14.35	15.81	17.57	19.78	21.71	20.89
2018-12-14	10:25:08 AM	100	10.88	21.23	37.89	25.92	7.08	10.98	11.49	12.91	13.94	15.21	17.64	19.67	21.74	23.30	21.28
2018-12-14	10:26:48 AM	200	10.55	22.34	38.11	26.31	7.07	10.61	11.23	12.72	13.92	15.32	17.87	20.06	22.22	24.00	22.23

Table E18: Raw RTD and thermocouple data sample for 4-36 at 5.5LPM

Date	GMT -5hrs	Time (s)	RTD's					THERMOCOUPLES									
			T _a (°C)	T _{co} (°C)	T _h (°C)	T _{ho} (°C)	Flow LPM	T _a (°C)	T ₁ (°C)	T ₂ (°C)	T ₃ (°C)	T ₄ (°C)	T ₅ (°C)	T ₆ (°C)	T ₇ (°C)	T ₈ (°C)	T _{co} (°C)
2018-12-15	3:48:30 PM	1	22.05	22.46	23.44	22.48	5.18	22.24	22.33	22.38	22.42	22.42	22.35	22.32	22.29	22.30	22.40
2018-12-15	3:48:31 PM	2	21.83	22.46	23.68	22.52	5.19	22.09	22.25	22.30	22.40	22.42	22.35	22.33	22.31	22.31	22.41
2018-12-15	3:48:32 PM	3	21.6	22.47	24.11	22.55	5.19	21.94	22.12	22.20	22.39	22.43	22.37	22.35	22.33	22.32	22.42
2018-12-15	3:48:34 PM	5	21.07	22.49	24.95	22.61	5.23	21.51	21.72	21.87	22.27	22.41	22.38	22.36	22.35	22.34	22.43
2018-12-15	3:48:37 PM	8	20.18	22.52	26.71	22.71	5.29	20.74	20.91	21.14	21.86	22.26	22.36	22.40	22.41	22.41	22.49
2018-12-15	3:48:39 PM	10	19.22	22.58	28.66	22.84	5.3	20.18	20.33	20.58	21.45	22.05	22.30	22.42	22.48	22.49	22.57
2018-12-15	3:48:44 PM	15	17.56	22.84	31.8	23.7	5.42	18.74	18.74	19.08	20.13	21.08	21.77	22.30	22.65	22.80	22.87
2018-12-15	3:48:49 PM	20	16.35	23.19	33.56	24.97	5.43	17.42	17.36	17.70	18.77	19.88	20.90	21.85	22.63	23.11	23.26
2018-12-15	3:48:59 PM	30	14.17	23.36	35.84	28.07	5.54	15.23	15.17	15.44	16.46	17.59	18.87	20.29	21.66	22.93	23.24
2018-12-15	3:49:19 PM	50	12.08	21.51	37.06	28.74	5.8	12.75	12.78	13.08	13.83	14.81	16.15	17.76	19.61	21.40	21.48
2018-12-15	3:50:09 PM	100	10.71	20.11	37.69	28.19	5.58	11.03	11.17	11.47	12.19	13.06	14.42	16.05	18.32	20.84	20.19
2018-12-15	3:51:49 PM	200	10.21	20.18	37.98	27.83	5.57	10.45	10.64	10.98	11.71	12.62	14.10	15.94	18.65	21.65	20.26

Appendix F: Coil Set Surface and Estimated Water Temperature Data Tables

Table F1: R3-36 mains-side temperature values at 14LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.51	22.49	22.47	20.99	17.74	16.43	13.75	12.18	10.79	10.00	9.63	9.51
	0.07	22.52	22.50	22.48	21.10	18.06	16.82	14.27	12.78	11.41	10.62	10.26	10.15
	0.13	22.54	22.51	22.49	21.21	18.39	17.21	14.79	13.37	12.02	11.25	10.90	10.78
	0.20	22.55	22.52	22.51	21.32	18.71	17.60	15.31	13.97	12.64	11.87	11.53	11.42
	0.27	22.56	22.54	22.52	21.43	19.03	18.00	15.83	14.56	13.25	12.49	12.16	12.06
	0.33	22.57	22.55	22.53	21.54	19.35	18.39	16.35	15.16	13.87	13.12	12.80	12.69
	0.40	22.59	22.56	22.54	21.65	19.68	18.78	16.87	15.75	14.49	13.74	13.43	13.33
	0.47	22.60	22.57	22.55	21.76	20.00	19.17	17.39	16.35	15.10	14.36	14.06	13.97
	0.53	22.61	22.58	22.57	21.86	20.32	19.56	17.90	16.94	15.72	14.99	14.70	14.60
	0.60	22.62	22.59	22.58	21.97	20.64	19.95	18.42	17.54	16.33	15.61	15.33	15.24
	0.67	22.64	22.60	22.59	22.08	20.97	20.34	18.94	18.13	16.95	16.23	15.96	15.88
	0.73	22.65	22.61	22.60	22.19	21.29	20.73	19.46	18.73	17.57	16.86	16.60	16.51
	0.80	22.66	22.63	22.61	22.30	21.61	21.13	19.98	19.32	18.18	17.48	17.23	17.15
	0.87	22.67	22.64	22.63	22.41	21.93	21.52	20.50	19.92	18.80	18.10	17.86	17.79
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.93	22.69	22.65	22.64	22.52	22.26	21.91	21.02	20.51	19.41	18.73	18.50	18.42
	1.00	22.70	22.66	22.65	22.63	22.58	22.30	21.54	21.11	20.03	19.35	19.13	19.06
	0.00	22.36	22.33	22.26	21.14	18.83	17.42	14.73	13.09	11.47	10.39	9.80	9.65
	0.11	22.40	22.36	22.32	21.06	18.71	17.44	15.35	14.13	12.89	12.16	11.86	11.70
	0.22	22.42	22.39	22.33	21.14	18.77	17.49	15.37	14.09	12.85	12.16	11.80	11.70
	0.33	22.42	22.40	22.39	21.67	19.59	18.50	16.87	15.75	14.60	13.96	13.67	13.54
	0.44	22.46	22.43	22.45	22.01	20.12	19.14	17.77	16.79	15.72	15.13	14.92	14.78
	0.56	22.43	22.41	22.41	22.33	20.98	20.12	19.01	18.15	17.11	16.50	16.33	16.19
	0.67	22.44	22.41	22.43	22.41	21.53	21.05	20.71	20.19	19.40	18.94	18.83	18.75
	0.78	22.46	22.43	22.46	22.48	21.93	21.64	21.62	21.24	20.55	20.14	20.04	20.01
	0.89	22.50	22.48	22.50	22.50	22.36	22.14	21.88	21.65	21.00	20.56	20.43	20.41
	1.00	22.45	22.42	22.44	22.44	22.25	21.85	21.24	20.77	19.77	19.15	18.92	18.86
COILSET SURFACE TEMPERATURE (°C)	0.00	22.51	22.49	22.47	20.99	17.74	16.43	13.75	12.18	10.79	10.00	9.63	9.51
	0.07	21.84	21.86	21.72	20.00	17.62	16.50	14.74	13.67	12.57	11.77	11.67	11.35
	0.13	21.89	21.88	21.82	20.34	18.00	16.92	15.22	14.15	13.02	12.28	12.17	11.78
	0.20	21.87	21.89	21.89	20.70	18.46	17.46	15.98	14.99	13.90	13.16	13.05	12.72
	0.27	21.85	21.86	21.86	21.00	18.92	18.01	16.66	15.68	14.68	13.98	13.92	13.55
	0.33	21.83	21.86	21.88	21.26	19.29	18.44	17.25	16.32	15.32	14.64	14.58	14.21
	0.40	21.85	21.85	21.89	21.48	19.71	18.93	17.89	17.00	16.04	15.39	15.36	14.98
	0.47	21.86	21.88	21.91	21.67	20.08	19.38	18.48	17.65	16.70	16.07	16.02	15.69
	0.53	21.84	21.86	21.90	21.78	20.42	19.81	19.10	18.33	17.44	16.81	16.77	16.46
	0.60	21.84	21.86	21.91	21.85	20.72	20.20	19.62	18.91	18.06	17.45	17.46	17.11
	0.67	21.84	21.87	21.90	21.89	20.99	20.55	20.11	19.48	18.66	18.02	18.06	17.76
	0.73	21.85	21.85	21.90	21.93	21.30	20.96	20.70	20.14	19.39	18.75	18.78	18.50
	0.80	21.81	21.84	21.89	21.92	21.55	21.30	21.22	20.75	20.04	19.44	19.53	19.20
	0.87	21.82	21.86	21.91	21.95	21.81	21.73	21.90	21.56	20.90	20.32	20.40	20.12
	0.93	21.94	21.98	22.01	22.07	21.92	21.80	21.91	21.63	20.89	20.31	20.42	20.17
	1.00	22.70	22.66	22.65	22.63	22.58	22.30	21.54	21.11	20.03	19.35	19.13	19.06

Table F2: R3-36 mains-side temperature values at 12LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.47	22.46	22.43	21.08	19.69	17.76	14.67	13.35	11.81	10.74	10.28	10.14
	0.07	22.48	22.47	22.44	21.18	19.89	18.08	15.16	13.93	12.45	11.39	10.93	10.80
	0.13	22.49	22.48	22.46	21.29	20.08	18.40	15.66	14.50	13.08	12.04	11.59	11.46
	0.20	22.51	22.50	22.47	21.39	20.28	18.73	16.15	15.08	13.72	12.68	12.24	12.12
	0.27	22.52	22.51	22.49	21.49	20.48	19.05	16.65	15.66	14.36	13.33	12.90	12.79
	0.33	22.53	22.52	22.50	21.60	20.68	19.37	17.14	16.23	14.99	13.98	13.55	13.45
	0.40	22.54	22.53	22.51	21.70	20.87	19.69	17.64	16.81	15.63	14.63	14.21	14.11
	0.47	22.55	22.54	22.53	21.80	21.07	20.01	18.13	17.39	16.27	15.28	14.86	14.77
	0.53	22.57	22.56	22.54	21.91	21.27	20.34	18.63	17.96	16.90	15.92	15.52	15.43
	0.60	22.58	22.57	22.56	22.01	21.47	20.66	19.12	18.54	17.54	16.57	16.17	16.09
	0.67	22.59	22.58	22.57	22.11	21.66	20.98	19.62	19.12	18.18	17.22	16.83	16.75
	0.73	22.60	22.59	22.58	22.22	21.86	21.30	20.11	19.69	18.81	17.87	17.48	17.41
	0.80	22.61	22.60	22.60	22.32	22.06	21.62	20.61	20.27	19.45	18.52	18.14	18.08
	0.87	22.63	22.62	22.61	22.42	22.26	21.95	21.10	20.85	20.09	19.16	18.79	18.74
	0.93	22.64	22.63	22.63	22.53	22.45	22.27	21.60	21.42	20.72	19.81	19.45	19.40
	1.00	22.65	22.64	22.64	22.63	22.65	22.59	22.09	22.00	21.36	20.46	20.10	20.06
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.33	22.31	22.29	21.63	19.85	18.60	16.02	14.23	12.42	11.12	10.43	10.28
	0.11	22.40	22.38	22.36	21.60	19.72	18.52	16.46	15.25	13.89	12.97	12.58	12.46
	0.22	22.42	22.41	22.39	21.79	19.99	18.82	16.67	15.36	13.97	13.02	12.59	12.47
	0.33	22.42	22.42	22.41	22.14	20.65	19.67	18.02	17.01	15.80	14.91	14.51	14.43
	0.44	22.45	22.45	22.46	22.34	21.04	20.17	18.83	18.03	16.94	16.10	15.77	15.70
	0.56	22.45	22.44	22.43	22.44	21.71	21.03	19.95	19.34	18.33	17.54	17.22	17.15
	0.67	22.45	22.46	22.46	22.49	22.08	21.69	21.41	21.23	20.53	19.92	19.68	19.69
	0.78	22.49	22.49	22.49	22.53	22.38	22.18	22.23	22.26	21.71	21.16	20.98	21.00
	0.89	22.53	22.53	22.53	22.54	22.55	22.51	22.49	22.59	22.35	21.81	21.59	21.60
	1.00	22.46	22.46	22.45	22.46	22.46	22.28	21.89	21.76	21.01	20.25	19.92	19.87
COILSET SURFACE TEMPERATURE (°C)	0.00	22.47	22.46	22.43	21.08	19.69	17.76	14.67	13.35	11.81	10.74	10.28	10.14
	0.07	21.85	21.86	21.78	20.77	18.99	17.80	16.08	14.88	13.66	12.77	12.47	12.26
	0.13	21.84	21.85	21.79	21.01	19.25	18.11	16.47	15.31	14.07	13.20	12.89	12.73
	0.20	21.88	21.90	21.85	21.30	19.67	18.64	17.19	16.15	14.97	14.12	13.83	13.61
	0.27	21.88	21.91	21.85	21.49	20.05	19.10	17.85	16.90	15.76	14.94	14.66	14.47
	0.33	21.85	21.86	21.83	21.61	20.36	19.47	18.36	17.50	16.41	15.60	15.32	15.19
	0.40	21.86	21.87	21.86	21.73	20.70	19.90	18.98	18.22	17.17	16.38	16.10	15.99
	0.47	21.90	21.91	21.88	21.81	20.99	20.30	19.54	18.89	17.87	17.10	16.87	16.69
	0.53	21.89	21.89	21.86	21.82	21.22	20.60	19.99	19.42	18.47	17.73	17.50	17.35
	0.60	21.92	21.93	21.90	21.88	21.49	20.97	20.53	20.07	19.16	18.43	18.23	18.06
	0.67	21.93	21.95	21.91	21.88	21.69	21.27	21.03	20.69	19.87	19.16	18.98	18.80
	0.73	21.94	21.94	21.91	21.88	21.88	21.59	21.53	21.33	20.56	19.92	19.75	19.59
	0.80	21.94	21.94	21.93	21.88	22.06	21.88	22.01	21.93	21.24	20.61	20.49	20.30
	0.87	21.92	21.96	21.93	21.88	22.18	22.15	22.53	22.56	21.98	21.37	21.28	21.13
	0.93	21.93	21.96	21.93	21.91	22.21	22.21	22.62	22.76	22.20	21.60	21.52	21.36
	1.00	22.65	22.64	22.64	22.63	22.65	22.59	22.09	22.00	21.36	20.46	20.10	20.06

Table F3: R3-36 mains-side temperature values at 10LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.44	22.37	22.29	21.46	19.09	17.51	15.12	13.56	11.99	10.78	10.14	9.95
	0.07	22.47	22.40	22.33	21.55	19.34	17.86	15.61	14.15	12.67	11.48	10.85	10.67
	0.13	22.50	22.44	22.37	21.65	19.58	18.20	16.10	14.74	13.34	12.18	11.56	11.39
	0.20	22.53	22.47	22.41	21.74	19.83	18.55	16.58	15.33	14.02	12.87	12.28	12.11
	0.27	22.56	22.51	22.45	21.83	20.08	18.89	17.07	15.92	14.69	13.57	12.99	12.83
	0.33	22.59	22.54	22.49	21.93	20.33	19.24	17.56	16.51	15.37	14.27	13.70	13.55
	0.40	22.62	22.57	22.53	22.02	20.57	19.59	18.05	17.10	16.05	14.97	14.41	14.27
	0.47	22.65	22.61	22.57	22.11	20.82	19.93	18.54	17.69	16.72	15.67	15.12	14.99
	0.53	22.67	22.64	22.60	22.21	21.07	20.28	19.02	18.28	17.40	16.36	15.84	15.70
	0.60	22.70	22.68	22.64	22.30	21.32	20.62	19.51	18.87	18.07	17.06	16.55	16.42
	0.67	22.73	22.71	22.68	22.39	21.56	20.97	20.00	19.46	18.75	17.76	17.26	17.14
	0.73	22.76	22.74	22.72	22.49	21.81	21.32	20.49	20.05	19.43	18.46	17.97	17.86
	0.80	22.79	22.78	22.76	22.58	22.06	21.66	20.98	20.64	20.10	19.16	18.68	18.58
	0.87	22.82	22.81	22.80	22.67	22.31	22.01	21.46	21.23	20.78	19.85	19.40	19.30
	0.93	22.85	22.85	22.84	22.77	22.55	22.35	21.95	21.82	21.45	20.55	20.11	20.02
	1.00	22.88	22.88	22.88	22.86	22.80	22.70	22.44	22.41	22.13	21.25	20.82	20.74
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.35	22.27	22.03	21.14	19.50	18.46	16.18	14.55	12.69	11.24	10.37	10.16
	0.11	22.46	22.39	22.16	21.23	19.58	18.67	16.85	15.70	14.29	13.20	12.64	12.46
	0.22	22.47	22.42	22.26	21.43	19.81	18.85	17.00	15.82	14.39	13.32	12.74	12.54
	0.33	22.53	22.49	22.44	21.88	20.56	19.77	18.39	17.52	16.34	15.34	14.84	14.63
	0.44	22.60	22.56	22.55	22.16	21.00	20.34	19.23	18.56	17.55	16.63	16.18	15.98
	0.56	22.61	22.58	22.57	22.39	21.58	21.07	20.26	19.82	18.93	18.09	17.70	17.53
	0.67	22.66	22.63	22.63	22.55	22.14	21.95	21.78	21.74	21.20	20.54	20.24	20.13
	0.78	22.70	22.66	22.66	22.61	22.44	22.43	22.59	22.79	22.43	21.85	21.60	21.55
	0.89	22.72	22.71	22.71	22.66	22.61	22.59	22.78	23.07	22.94	22.45	22.21	22.17
	1.00	22.73	22.71	22.70	22.66	22.58	22.45	22.24	22.22	21.82	21.06	20.66	20.60
COILSET SURFACE TEMPERATURE (°C)	0.00	22.44	22.37	22.29	21.46	19.09	17.51	15.12	13.56	11.99	10.78	10.14	9.95
	0.07	21.75	21.63	21.18	20.11	18.45	17.62	16.06	15.07	13.78	12.95	12.47	12.34
	0.13	21.81	21.73	21.37	20.43	18.83	18.03	16.53	15.60	14.31	13.44	13.00	12.87
	0.20	21.81	21.74	21.50	20.70	19.20	18.49	17.17	16.34	15.15	14.34	13.93	13.85
	0.27	21.85	21.80	21.62	20.99	19.64	19.01	17.87	17.15	16.04	15.19	14.81	14.73
	0.33	21.86	21.81	21.66	21.19	19.97	19.40	18.43	17.80	16.74	15.96	15.58	15.53
	0.40	21.90	21.85	21.70	21.38	20.34	19.83	19.02	18.51	17.50	16.75	16.40	16.32
	0.47	21.92	21.87	21.75	21.53	20.65	20.23	19.55	19.12	18.19	17.49	17.17	17.12
	0.53	21.92	21.89	21.76	21.63	20.93	20.58	20.07	19.78	18.91	18.26	17.95	17.88
	0.60	21.95	21.91	21.78	21.71	21.19	20.92	20.60	20.39	19.62	18.99	18.74	18.68
	0.67	22.03	21.98	21.85	21.80	21.48	21.29	21.13	21.03	20.33	19.73	19.46	19.45
	0.73	22.06	22.01	21.88	21.87	21.70	21.63	21.63	21.66	21.08	20.49	20.26	20.30
	0.80	22.05	22.00	21.87	21.86	21.88	21.90	22.13	22.28	21.80	21.27	21.07	21.12
	0.87	22.08	22.03	21.91	21.91	22.06	22.21	22.65	22.95	22.60	22.11	21.94	21.99
	0.93	22.09	22.02	21.90	21.89	22.04	22.19	22.65	23.04	22.75	22.31	22.16	22.24
	1.00	22.88	22.88	22.88	22.86	22.80	22.70	22.44	22.41	22.13	21.25	20.82	20.74

Table F4: R3-36 mains-side temperature values at 9LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	21.66	21.22	20.97	19.65	18.14	16.82	14.84	13.51	12.01	10.91	10.27	10.07
	0.07	21.73	21.32	21.08	19.85	18.44	17.20	15.34	14.12	12.71	11.63	11.01	10.82
	0.13	21.80	21.41	21.20	20.05	18.74	17.58	15.85	14.72	13.40	12.35	11.74	11.56
	0.20	21.86	21.51	21.31	20.25	19.04	17.96	16.35	15.33	14.10	13.08	12.48	12.31
	0.27	21.93	21.61	21.43	20.45	19.33	18.34	16.85	15.94	14.80	13.80	13.22	13.06
	0.33	22.00	21.71	21.54	20.65	19.63	18.72	17.36	16.54	15.50	14.52	13.95	13.81
	0.40	22.07	21.80	21.65	20.85	19.93	19.10	17.86	17.15	16.19	15.24	14.69	14.55
	0.47	22.14	21.90	21.77	21.05	20.23	19.48	18.36	17.76	16.89	15.96	15.43	15.30
	0.53	22.20	22.00	21.88	21.26	20.53	19.86	18.87	18.36	17.59	16.69	16.16	16.05
	0.60	22.27	22.10	22.00	21.46	20.83	20.24	19.37	18.97	18.29	17.41	16.90	16.80
	0.67	22.34	22.19	22.11	21.66	21.13	20.62	19.87	19.58	18.98	18.13	17.64	17.54
	0.73	22.41	22.29	22.22	21.86	21.43	21.00	20.38	20.18	19.68	18.85	18.37	18.29
	0.80	22.48	22.39	22.34	22.06	21.72	21.38	20.88	20.79	20.38	19.57	19.11	19.04
	0.87	22.54	22.49	22.45	22.26	22.02	21.76	21.38	21.40	21.08	20.30	19.85	19.79
	0.93	22.61	22.58	22.57	22.46	22.32	22.14	21.89	22.00	21.77	21.02	20.58	20.53
	1.00	22.68	22.68	22.68	22.66	22.62	22.52	22.39	22.61	22.47	21.74	21.32	21.28
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	21.96	21.68	21.31	20.45	19.05	18.17	16.25	14.79	13.00	11.49	10.53	10.29
	0.11	21.95	21.60	21.15	20.15	18.89	18.15	16.79	15.77	14.52	13.39	12.85	12.70
	0.22	22.08	21.80	21.42	20.49	19.19	18.42	16.98	15.95	14.68	13.59	12.94	12.84
	0.33	22.23	22.07	21.79	21.05	20.01	19.41	18.44	17.74	16.69	15.69	15.14	15.05
	0.44	22.35	22.25	22.04	21.43	20.54	20.04	19.32	18.83	17.92	17.01	16.56	16.47
	0.56	22.39	22.35	22.26	21.89	21.21	20.84	20.40	20.11	19.34	18.52	18.09	18.05
	0.67	22.44	22.42	22.38	22.23	21.95	21.83	21.98	22.06	21.62	20.98	20.70	20.69
	0.78	22.47	22.46	22.44	22.41	22.35	22.36	22.81	23.10	22.88	22.36	22.13	22.15
	0.89	22.50	22.51	22.49	22.48	22.52	22.56	23.06	23.47	23.41	22.97	22.77	22.80
	1.00	22.49	22.49	22.48	22.46	22.36	22.25	22.26	22.44	22.19	21.49	21.10	21.07
COILSET SURFACE TEMPERATURE (°C)	0.00	21.66	21.22	20.97	19.65	18.14	16.82	14.84	13.51	12.01	10.91	10.27	10.07
	0.07	21.13	20.64	20.12	19.09	17.87	17.18	16.02	15.11	14.01	13.10	12.57	12.41
	0.13	21.34	20.89	20.43	19.43	18.28	17.62	16.56	15.72	14.61	13.76	13.21	13.03
	0.20	21.50	21.13	20.72	19.81	18.73	18.16	17.31	16.57	15.52	14.72	14.17	14.03
	0.27	21.65	21.36	21.02	20.20	19.25	18.74	18.06	17.43	16.46	15.66	15.13	15.03
	0.33	21.69	21.47	21.19	20.47	19.59	19.17	18.59	18.06	17.14	16.37	15.89	15.80
	0.40	21.74	21.59	21.37	20.75	20.00	19.64	19.26	18.80	17.94	17.22	16.76	16.71
	0.47	21.80	21.68	21.53	21.00	20.35	20.05	19.78	19.41	18.64	17.94	17.49	17.41
	0.53	21.83	21.75	21.63	21.24	20.71	20.48	20.34	20.10	19.36	18.67	18.27	18.22
	0.60	21.85	21.78	21.71	21.44	21.03	20.87	20.91	20.75	20.13	19.54	19.15	19.06
	0.67	21.90	21.84	21.80	21.62	21.33	21.27	21.46	21.42	20.87	20.25	19.90	19.86
	0.73	21.94	21.88	21.86	21.76	21.64	21.67	22.06	22.13	21.69	21.11	20.80	20.73
	0.80	21.94	21.89	21.89	21.87	21.89	22.00	22.53	22.72	22.38	21.83	21.58	21.54
	0.87	21.99	21.95	21.94	22.01	22.19	22.40	23.14	23.48	23.23	22.71	22.52	22.50
	0.93	21.99	21.97	21.96	22.02	22.25	22.46	23.24	23.67	23.52	23.03	22.88	22.81
	1.00	22.68	22.68	22.68	22.66	22.62	22.52	22.39	22.61	22.47	21.74	21.32	21.28

Table F5: R3-36 mains-side temperature values at 7LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	21.89	21.59	21.22	20.06	18.88	18.15	16.26	14.82	13.00	11.47	10.44	10.13
	0.07	21.96	21.68	21.33	20.25	19.15	18.46	16.71	15.38	13.71	12.26	11.26	10.97
	0.13	22.03	21.77	21.45	20.44	19.41	18.78	17.15	15.94	14.41	13.04	12.08	11.80
	0.20	22.10	21.86	21.56	20.63	19.68	19.09	17.60	16.51	15.12	13.83	12.91	12.64
	0.27	22.17	21.95	21.68	20.81	19.94	19.40	18.04	17.07	15.83	14.62	13.73	13.48
	0.33	22.24	22.04	21.79	21.00	20.21	19.72	18.49	17.63	16.54	15.41	14.55	14.32
	0.40	22.31	22.13	21.90	21.19	20.47	20.03	18.94	18.19	17.24	16.19	15.37	15.15
	0.47	22.38	22.22	22.02	21.38	20.74	20.34	19.38	18.75	17.95	16.98	16.19	15.99
	0.53	22.46	22.31	22.13	21.57	21.00	20.66	19.83	19.32	18.66	17.77	17.02	16.83
	0.60	22.53	22.40	22.25	21.76	21.27	20.97	20.27	19.88	19.37	18.56	17.84	17.67
	0.67	22.60	22.49	22.36	21.95	21.53	21.28	20.72	20.44	20.07	19.34	18.66	18.50
	0.73	22.67	22.58	22.47	22.14	21.80	21.60	21.17	21.00	20.78	20.13	19.48	19.34
	0.80	22.74	22.67	22.59	22.32	22.06	21.91	21.61	21.56	21.49	20.92	20.30	20.18
	0.87	22.81	22.76	22.70	22.51	22.33	22.22	22.06	22.13	22.20	21.71	21.13	21.02
	0.93	22.88	22.85	22.82	22.70	22.59	22.54	22.50	22.69	22.90	22.49	21.95	21.85
	1.00	22.95	22.94	22.93	22.89	22.86	22.85	22.95	23.25	23.61	23.28	22.77	22.69
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.07	21.86	21.63	21.02	19.99	19.28	17.63	16.21	14.16	12.18	10.78	10.39
	0.11	22.17	21.94	21.64	20.97	19.89	19.31	18.10	17.21	15.89	14.47	13.65	13.40
	0.22	22.29	22.11	21.86	21.27	20.26	19.67	18.43	17.50	16.13	14.74	13.85	13.57
	0.33	22.49	22.37	22.21	21.77	21.01	20.58	19.77	19.17	18.24	17.12	16.36	16.13
	0.44	22.59	22.53	22.42	22.08	21.47	21.13	20.55	20.18	19.40	18.43	17.82	17.65
	0.56	22.64	22.60	22.57	22.40	22.00	21.81	21.50	21.33	20.84	20.05	19.48	19.36
	0.67	22.72	22.70	22.67	22.61	22.54	22.58	22.84	23.13	23.05	22.57	22.19	22.11
	0.78	22.76	22.74	22.71	22.71	22.80	22.98	23.54	24.05	24.27	23.98	23.70	23.66
	0.89	22.81	22.79	22.77	22.76	22.81	22.94	23.45	24.06	24.65	24.61	24.40	24.45
	1.00	22.76	22.76	22.74	22.71	22.68	22.69	22.86	23.16	23.38	23.02	22.57	22.48
COILSET SURFACE TEMPERATURE (°C)	0.00	21.89	21.59	21.22	20.06	18.88	18.15	16.26	14.82	13.00	11.47	10.44	10.13
	0.07	21.48	21.28	21.01	20.35	19.17	18.37	17.22	16.26	14.87	13.49	12.69	12.40
	0.13	21.61	21.46	21.25	20.66	19.54	18.81	17.73	16.84	15.51	14.20	13.39	13.18
	0.20	21.76	21.65	21.48	20.98	19.97	19.31	18.40	17.65	16.44	15.22	14.47	14.28
	0.27	21.83	21.77	21.67	21.25	20.38	19.78	19.02	18.42	17.33	16.21	15.50	15.34
	0.33	21.87	21.86	21.78	21.48	20.69	20.16	19.56	19.08	18.13	17.07	16.45	16.23
	0.40	21.91	21.92	21.87	21.65	20.98	20.54	20.10	19.75	18.92	17.93	17.34	17.17
	0.47	21.98	21.99	21.97	21.83	21.27	20.89	20.58	20.37	19.65	18.77	18.19	18.04
	0.53	22.01	22.03	22.02	21.95	21.50	21.19	21.05	20.95	20.41	19.59	19.08	18.97
	0.60	22.03	22.05	22.05	22.02	21.71	21.47	21.56	21.58	21.20	20.48	19.99	19.91
	0.67	22.06	22.09	22.09	22.11	21.90	21.74	21.99	22.20	21.96	21.34	20.93	20.84
	0.73	22.12	22.15	22.14	22.19	22.08	22.02	22.44	22.78	22.73	22.25	21.87	21.76
	0.80	22.13	22.16	22.16	22.23	22.22	22.26	22.88	23.37	23.47	23.13	22.76	22.70
	0.87	22.19	22.19	22.21	22.28	22.37	22.49	23.32	24.00	24.31	24.07	23.81	23.74
	0.93	22.17	22.21	22.20	22.27	22.36	22.49	23.39	24.13	24.59	24.44	24.28	24.26
	1.00	22.95	22.94	22.93	22.89	22.86	22.85	22.95	23.25	23.61	23.28	22.77	22.69

Table F6: R3-36 mains-side temperature values at 5.5LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.05	21.85	21.36	20.83	19.94	19.03	17.54	16.24	14.17	12.03	10.58	10.10
	0.07	22.10	21.91	21.46	20.96	20.13	19.29	17.91	16.71	14.82	12.86	11.47	11.01
	0.13	22.15	21.98	21.55	21.10	20.33	19.55	18.27	17.17	15.47	13.68	12.35	11.91
	0.20	22.20	22.04	21.65	21.23	20.52	19.80	18.64	17.64	16.12	14.51	13.24	12.82
	0.27	22.25	22.11	21.75	21.36	20.71	20.06	19.00	18.10	16.77	15.33	14.12	13.73
	0.33	22.30	22.17	21.85	21.49	20.91	20.32	19.37	18.57	17.42	16.16	15.01	14.63
	0.40	22.35	22.23	21.94	21.63	21.10	20.58	19.73	19.03	18.07	16.98	15.90	15.54
	0.47	22.40	22.30	22.04	21.76	21.29	20.84	20.10	19.50	18.72	17.81	16.78	16.45
	0.53	22.46	22.36	22.14	21.89	21.49	21.09	20.46	19.96	19.37	18.63	17.67	17.35
	0.60	22.51	22.43	22.24	22.02	21.68	21.35	20.83	20.43	20.02	19.46	18.55	18.26
	0.67	22.56	22.49	22.33	22.16	21.87	21.61	21.19	20.89	20.67	20.28	19.44	19.17
	0.73	22.61	22.55	22.43	22.29	22.07	21.87	21.56	21.36	21.32	21.11	20.33	20.07
	0.80	22.66	22.62	22.53	22.42	22.26	22.13	21.92	21.82	21.97	21.93	21.21	20.98
	0.87	22.71	22.68	22.63	22.55	22.45	22.38	22.29	22.29	22.62	22.76	22.10	21.89
	0.93	22.76	22.75	22.72	22.69	22.65	22.64	22.65	22.75	23.27	23.58	22.98	22.79
	1.00	22.81	22.81	22.82	22.82	22.84	22.90	23.02	23.22	23.92	24.41	23.87	23.70
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.12	21.98	21.77	21.35	20.58	20.03	18.61	17.30	15.08	12.66	10.82	10.27
	0.11	22.22	22.09	21.88	21.42	20.58	20.01	18.52	17.88	16.60	14.91	13.73	13.34
	0.22	22.37	22.26	22.12	21.76	21.07	20.52	19.16	18.28	17.10	15.46	14.19	13.79
	0.33	22.48	22.43	22.35	22.12	21.57	21.14	19.97	19.64	18.91	17.79	16.74	16.39
	0.44	22.56	22.53	22.48	22.35	21.91	21.56	20.59	20.53	20.02	19.12	18.24	17.92
	0.56	22.57	22.56	22.54	22.49	22.27	22.05	21.41	21.51	21.36	20.84	20.05	19.76
	0.67	22.60	22.59	22.58	22.59	22.53	22.45	22.20	22.90	23.34	23.29	22.75	22.58
	0.78	22.63	22.65	22.64	22.65	22.68	22.71	22.78	23.79	24.56	24.86	24.48	24.38
	0.89	22.66	22.67	22.67	22.70	22.73	22.78	22.99	23.91	25.05	25.74	25.53	25.50
	1.00	22.63	22.63	22.63	22.65	22.68	22.73	22.90	23.16	23.81	24.17	23.62	23.46
COILSET SURFACE TEMPERATURE (°C)	0.00	22.05	21.85	21.36	20.83	19.94	19.03	17.54	16.24	14.17	12.03	10.58	10.10
	0.07	21.67	21.49	21.33	20.78	19.95	19.49	18.45	17.26	15.67	13.94	12.80	12.39
	0.13	21.79	21.67	21.53	21.03	20.29	19.88	18.90	17.81	16.36	14.75	13.64	13.25
	0.20	21.89	21.80	21.71	21.29	20.62	20.24	19.39	18.45	17.22	15.78	14.72	14.39
	0.27	21.94	21.88	21.82	21.47	20.92	20.62	19.89	19.09	18.10	16.79	15.82	15.50
	0.33	21.98	21.96	21.93	21.65	21.19	20.92	20.32	19.65	18.84	17.73	16.81	16.51
	0.40	22.01	21.99	22.00	21.77	21.40	21.20	20.73	20.18	19.58	18.60	17.77	17.51
	0.47	22.03	22.03	22.05	21.87	21.60	21.45	21.11	20.71	20.27	19.47	18.71	18.46
	0.53	22.06	22.06	22.08	21.95	21.78	21.70	21.51	21.23	20.99	20.35	19.67	19.48
	0.60	22.07	22.08	22.11	22.02	21.92	21.90	21.89	21.74	21.72	21.29	20.66	20.48
	0.67	22.13	22.15	22.17	22.10	22.03	22.08	22.23	22.26	22.45	22.20	21.67	21.50
	0.73	22.15	22.17	22.21	22.15	22.13	22.25	22.57	22.78	23.17	23.09	22.72	22.53
	0.80	22.16	22.18	22.24	22.20	22.24	22.38	22.90	23.26	23.87	24.01	23.71	23.56
	0.87	22.17	22.18	22.23	22.19	22.31	22.55	23.25	23.82	24.67	25.02	24.86	24.76
	0.93	22.18	22.20	22.25	22.21	22.28	22.51	23.26	23.93	24.90	25.43	25.40	25.37
	1.00	22.81	22.81	22.82	22.82	22.84	22.90	23.02	23.22	23.92	24.41	23.87	23.70

Table F7: R3-60 mains-side temperature values at 14LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.04	21.90	21.58	19.94	17.01	15.85	13.47	12.11	10.92	10.21	9.87	9.75
	0.04	22.08	21.95	21.64	20.06	17.25	16.14	13.87	12.57	11.41	10.71	10.38	10.27
	0.08	22.12	21.99	21.70	20.18	17.48	16.42	14.28	13.04	11.90	11.22	10.90	10.78
	0.12	22.16	22.04	21.76	20.31	17.72	16.71	14.68	13.50	12.40	11.72	11.41	11.30
	0.16	22.20	22.09	21.82	20.43	17.96	17.00	15.08	13.96	12.89	12.23	11.93	11.82
	0.20	22.24	22.13	21.87	20.55	18.19	17.28	15.49	14.43	13.38	12.73	12.44	12.34
	0.24	22.28	22.18	21.93	20.67	18.43	17.57	15.89	14.89	13.87	13.23	12.96	12.85
	0.28	22.32	22.22	21.99	20.79	18.66	17.85	16.30	15.35	14.37	13.74	13.47	13.37
	0.32	22.36	22.27	22.05	20.92	18.90	18.14	16.70	15.82	14.86	14.24	13.99	13.89
	0.36	22.40	22.32	22.11	21.04	19.14	18.43	17.10	16.28	15.35	14.75	14.50	14.40
	0.40	22.44	22.36	22.17	21.16	19.37	18.71	17.51	16.74	15.84	15.25	15.01	14.92
	0.44	22.48	22.41	22.23	21.28	19.61	19.00	17.91	17.21	16.34	15.75	15.53	15.44
	0.48	22.52	22.46	22.29	21.40	19.85	19.29	18.31	17.67	16.83	16.26	16.04	15.96
	0.52	22.55	22.50	22.34	21.53	20.08	19.57	18.72	18.13	17.32	16.76	16.56	16.47
	0.56	22.59	22.55	22.40	21.65	20.32	19.86	19.12	18.59	17.81	17.27	17.07	16.99
	0.60	22.63	22.60	22.46	21.77	20.56	20.15	19.52	19.06	18.31	17.77	17.59	17.51
	0.64	22.67	22.64	22.52	21.89	20.79	20.43	19.93	19.52	18.80	18.27	18.10	18.03
	0.68	22.71	22.69	22.58	22.01	21.03	20.72	20.33	19.98	19.29	18.78	18.61	18.54
	0.72	22.75	22.74	22.64	22.14	21.27	21.01	20.73	20.45	19.78	19.28	19.13	19.06
	0.76	22.79	22.78	22.70	22.26	21.50	21.29	21.14	20.91	20.28	19.79	19.64	19.58
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.80	22.83	22.83	22.76	22.38	21.74	21.58	21.54	21.37	20.77	20.29	20.16	20.09
	0.84	22.87	22.87	22.81	22.50	21.97	21.86	21.95	21.84	21.26	20.79	20.67	20.61
	0.88	22.91	22.92	22.87	22.62	22.21	22.15	22.35	22.30	21.75	21.30	21.19	21.13
	0.92	22.95	22.97	22.93	22.75	22.45	22.44	22.75	22.76	22.25	21.80	21.70	21.65
	0.96	22.99	23.01	22.99	22.87	22.68	22.72	23.16	23.23	22.74	22.31	22.22	22.16
	1.00	23.03	23.06	23.05	22.99	22.92	23.01	23.56	23.69	23.23	22.81	22.73	22.68
	0.00	21.87	21.80	21.42	19.87	17.63	16.34	13.92	12.51	11.20	10.43	9.99	9.79
	0.11	21.97	21.93	21.51	19.79	17.51	16.33	14.35	13.14	12.09	11.54	11.20	11.07
	0.22	22.17	22.09	22.00	20.71	18.50	17.34	15.32	14.04	12.93	12.38	12.07	11.91
	0.33	22.43	22.30	22.24	21.62	19.75	18.77	17.21	16.11	15.09	14.62	14.34	14.17
COILSET SURFACE TEMPERATURE (°C)	0.44	22.56	22.50	22.42	22.14	20.67	19.83	18.53	17.53	16.60	16.13	15.88	15.75
	0.56	22.59	22.60	22.54	22.39	21.50	20.89	19.92	19.10	18.22	17.84	17.62	17.54
	0.67	22.69	22.67	22.67	22.58	22.30	21.96	21.30	20.64	19.78	19.41	19.19	19.12
	0.78	22.86	22.81	22.80	22.73	22.79	22.90	22.99	22.65	22.10	21.94	21.84	21.82
	0.89	23.03	22.97	22.92	22.84	23.10	23.57	24.15	23.98	23.55	23.51	23.42	23.45
	1.00	22.93	22.91	22.89	22.82	22.82	23.06	23.52	23.44	22.91	22.64	22.55	22.46
	0.00	22.04	21.90	21.58	19.94	17.01	15.85	13.47	12.11	10.92	10.21	9.87	9.75
	0.04	21.47	21.42	20.94	19.30	17.21	16.19	14.57	13.43	12.57	12.13	11.82	11.74
	0.08	21.56	21.50	21.21	19.67	17.56	16.48	14.87	13.73	12.87	12.42	12.11	12.03
	0.12	21.60	21.54	21.37	20.01	18.01	16.97	15.43	14.33	13.46	13.05	12.77	12.67
	0.16	21.64	21.54	21.44	20.14	18.00	16.88	15.20	13.98	13.02	12.57	12.24	12.16
	0.20	21.70	21.59	21.51	20.47	18.37	17.29	15.71	14.53	13.58	13.12	12.85	12.76
	0.24	21.82	21.66	21.61	20.79	18.84	17.83	16.37	15.24	14.34	13.91	13.66	13.56
	0.28	21.86	21.70	21.65	21.04	19.21	18.25	16.86	15.75	14.89	14.47	14.20	14.12
	0.32	21.94	21.78	21.71	21.27	19.53	18.62	17.30	16.21	15.33	14.93	14.65	14.58
	0.36	21.98	21.86	21.78	21.45	19.89	19.04	17.84	16.80	15.95	15.55	15.32	15.23
	0.40	22.00	21.94	21.84	21.60	20.22	19.43	18.29	17.26	16.42	16.04	15.80	15.73
	0.44	21.99	21.96	21.87	21.70	20.53	19.80	18.78	17.81	17.03	16.63	16.43	16.36
	0.48	22.00	22.00	21.93	21.78	20.80	20.15	19.23	18.31	17.50	17.15	16.94	16.88
	0.52	22.03	22.02	21.98	21.83	21.07	20.52	19.74	18.88	18.12	17.78	17.59	17.55
	0.56	22.08	22.07	22.04	21.92	21.37	20.90	20.27	19.45	18.72	18.45	18.30	18.24
	0.60	22.09	22.06	22.06	21.95	21.56	21.18	20.62	19.89	19.16	18.91	18.75	18.75
	0.64	22.14	22.09	22.09	22.00	21.79	21.51	21.15	20.45	19.79	19.57	19.41	19.41
	0.68	22.16	22.12	22.13	22.05	21.98	21.79	21.58	20.95	20.31	20.12	19.96	19.94
	0.72	22.26	22.20	22.20	22.13	22.22	22.14	22.07	21.51	20.89	20.73	20.59	20.61
	0.76	22.27	22.20	22.19	22.14	22.35	22.41	22.50	22.04	21.45	21.33	21.23	21.25
	0.80	22.29	22.22	22.20	22.16	22.46	22.64	22.89	22.51	21.97	21.89	21.79	21.80
	0.84	22.34	22.25	22.23	22.21	22.61	22.87	23.31	22.99	22.53	22.45	22.35	22.38
	0.88	22.37	22.29	22.25	22.24	22.68	23.07	23.67	23.42	22.99	22.96	22.87	22.88
	0.92	22.43	22.35	22.31	22.28	22.73	23.17	23.91	23.72	23.34	23.30	23.28	23.22
	0.96	22.42	22.36	22.31	22.27	22.68	23.18	24.08	24.02	23.71	23.66	23.68	23.67
	1.00	23.03	23.06	23.05	22.99	22.92	23.01	23.56	23.69	23.23	22.81	22.73	22.68

Table F8: R3-60 mains-side temperature values at 12LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.51	22.34	21.15	19.79	17.32	15.80	14.05	12.76	11.47	10.67	10.25	10.11
	0.04	22.53	22.37	21.22	19.92	17.55	16.10	14.45	13.23	11.98	11.19	10.78	10.65
	0.08	22.55	22.39	21.30	20.05	17.78	16.40	14.84	13.70	12.50	11.72	11.31	11.19
	0.12	22.57	22.42	21.37	20.17	18.01	16.70	15.24	14.17	13.01	12.24	11.85	11.72
	0.16	22.59	22.44	21.44	20.30	18.24	17.00	15.64	14.63	13.52	12.76	12.38	12.26
	0.20	22.61	22.47	21.52	20.43	18.47	17.30	16.03	15.10	14.03	13.28	12.91	12.80
	0.24	22.63	22.49	21.59	20.56	18.70	17.60	16.43	15.57	14.55	13.81	13.44	13.34
	0.28	22.64	22.52	21.66	20.69	18.93	17.91	16.82	16.04	15.06	14.33	13.98	13.88
	0.32	22.66	22.54	21.74	20.81	19.16	18.21	17.22	16.51	15.57	14.85	14.51	14.41
	0.36	22.68	22.57	21.81	20.94	19.39	18.51	17.62	16.98	16.09	15.38	15.04	14.95
	0.40	22.70	22.60	21.88	21.07	19.62	18.81	18.01	17.44	16.60	15.90	15.57	15.49
	0.44	22.72	22.62	21.96	21.20	19.85	19.11	18.41	17.91	17.11	16.42	16.11	16.03
	0.48	22.74	22.65	22.03	21.33	20.08	19.41	18.81	18.38	17.62	16.94	16.64	16.57
	0.52	22.76	22.67	22.10	21.45	20.32	19.71	19.20	18.85	18.14	17.47	17.17	17.10
	0.56	22.78	22.70	22.17	21.58	20.55	20.01	19.60	19.32	18.65	17.99	17.70	17.64
	0.60	22.80	22.72	22.25	21.71	20.78	20.31	20.00	19.79	19.16	18.51	18.24	18.18
	0.64	22.82	22.75	22.32	21.84	21.01	20.61	20.39	20.25	19.67	19.03	18.77	18.72
	0.68	22.84	22.78	22.39	21.97	21.24	20.91	20.79	20.72	20.19	19.56	19.30	19.26
	0.72	22.86	22.80	22.47	22.09	21.47	21.21	21.19	21.19	20.70	20.08	19.83	19.79
	0.76	22.87	22.83	22.54	22.22	21.70	21.52	21.58	21.66	21.21	20.60	20.37	20.33
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.80	22.89	22.85	22.61	22.35	21.93	21.82	21.98	22.13	21.73	21.13	20.90	20.87
	0.84	22.91	22.88	22.69	22.48	22.16	22.12	22.37	22.60	22.24	21.65	21.43	21.41
	0.88	22.93	22.90	22.76	22.61	22.39	22.42	22.77	23.06	22.75	22.17	21.96	21.95
	0.92	22.95	22.93	22.83	22.73	22.62	22.72	23.17	23.53	23.26	22.69	22.50	22.48
	0.96	22.97	22.95	22.91	22.86	22.85	23.02	23.56	24.00	23.78	23.22	23.03	23.02
	1.00	22.99	22.98	22.98	22.99	23.08	23.32	23.96	24.47	24.29	23.74	23.56	23.56
	0.00	22.19	21.69	21.09	19.73	17.78	16.64	14.46	13.14	11.76	10.84	10.32	10.12
	0.11	22.27	21.70	21.02	19.61	17.72	16.69	14.94	13.90	12.75	12.00	11.59	11.45
	0.22	22.52	22.32	21.84	20.56	18.71	17.68	15.94	14.87	13.64	12.87	12.50	12.35
	0.33	22.64	22.59	22.40	21.60	20.06	19.25	17.97	17.12	16.03	15.25	14.92	14.74
COILSET SURFACE TEMPERATURE (°C)	0.44	22.73	22.69	22.62	22.04	20.82	20.18	19.22	18.52	17.51	16.83	16.54	16.39
	0.56	22.74	22.73	22.69	22.46	21.64	21.19	20.59	20.09	19.19	18.59	18.36	18.22
	0.67	22.77	22.77	22.76	22.71	22.43	22.19	21.86	21.56	20.77	20.17	19.93	19.83
	0.78	22.82	22.84	22.84	22.88	23.04	23.27	23.72	23.74	23.22	22.82	22.71	22.63
	0.89	22.88	22.90	22.91	23.02	23.42	23.96	24.91	25.15	24.80	24.51	24.47	24.43
	1.00	22.78	22.80	22.79	22.83	23.00	23.25	23.98	24.26	23.89	23.43	23.29	23.26
	0.00	22.51	22.34	21.15	19.79	17.32	15.80	14.05	12.76	11.47	10.67	10.25	10.11
	0.04	21.88	21.53	20.90	19.71	17.86	16.93	15.45	14.37	13.37	12.64	12.22	12.27
	0.08	21.96	21.73	21.15	19.99	18.02	17.03	15.46	14.33	13.23	12.53	12.03	12.14
	0.12	22.00	21.86	21.40	20.30	18.41	17.39	15.90	14.76	13.70	12.97	12.57	12.62
	0.16	21.99	21.91	21.58	20.53	18.61	17.61	16.10	14.99	13.88	13.12	12.78	12.82
	0.20	22.04	21.98	21.76	20.83	19.00	18.06	16.67	15.58	14.50	13.78	13.40	13.45
	0.24	22.07	22.03	21.89	21.12	19.43	18.54	17.28	16.26	15.25	14.54	14.21	14.30
	0.28	22.10	22.07	22.00	21.38	19.78	18.98	17.80	16.81	15.80	15.13	14.77	14.83
	0.32	22.12	22.09	22.04	21.58	20.11	19.36	18.30	17.38	16.37	15.72	15.38	15.47
	0.36	22.15	22.12	22.08	21.77	20.45	19.76	18.80	17.97	16.97	16.30	16.00	16.12
	0.40	22.17	22.14	22.11	21.92	20.74	20.12	19.30	18.51	17.53	16.90	16.60	16.68
	0.44	22.16	22.12	22.11	22.00	20.95	20.40	19.69	18.97	18.01	17.41	17.14	17.25
	0.48	22.19	22.15	22.12	22.12	21.21	20.72	20.13	19.46	18.54	17.94	17.68	17.82
	0.52	22.22	22.21	22.18	22.22	21.50	21.10	20.65	20.08	19.20	18.63	18.36	18.49
	0.56	22.21	22.22	22.19	22.26	21.70	21.41	21.09	20.60	19.75	19.19	18.97	19.04
	0.60	22.24	22.25	22.23	22.31	21.90	21.71	21.52	21.07	20.28	19.75	19.50	19.60
	0.64	22.25	22.26	22.25	22.37	22.11	22.02	21.99	21.63	20.93	20.42	20.15	20.28
	0.68	22.29	22.31	22.30	22.42	22.30	22.31	22.44	22.14	21.45	20.95	20.74	20.84
	0.72	22.25	22.27	22.29	22.42	22.40	22.54	22.83	22.63	22.01	21.53	21.35	21.40
	0.76	22.29	22.30	22.33	22.46	22.55	22.80	23.24	23.13	22.57	22.12	21.92	22.03
	0.80	22.27	22.28	22.28	22.47	22.64	22.98	23.60	23.58	23.10	22.68	22.53	22.65
	0.84	22.30	22.33	22.33	22.53	22.76	23.23	24.04	24.11	23.70	23.30	23.13	23.27
	0.88	22.29	22.30	22.30	22.52	22.82	23.40	24.38	24.53	24.20	23.84	23.70	23.84
	0.92	22.25	22.27	22.28	22.49	22.84	23.42	24.53	24.76	24.44	24.13	24.02	24.15
	0.96	22.33	22.33	22.34	22.54	22.87	23.50	24.84	25.18	24.98	24.67	24.55	24.69
	1.00	22.99	22.98	22.98	22.99	23.08	23.32	23.96	24.47	24.29	23.74	23.56	23.56

Table F9: R3-60 mains-side temperature values at 10LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.14	21.83	21.36	20.21	18.43	16.88	14.58	13.32	11.57	10.47	9.84	9.67
	0.04	22.18	21.88	21.43	20.33	18.62	17.13	14.95	13.77	12.11	11.03	10.41	10.25
	0.08	22.22	21.94	21.50	20.45	18.81	17.39	15.33	14.21	12.64	11.59	10.99	10.83
	0.12	22.26	21.99	21.58	20.56	18.99	17.64	15.70	14.66	13.18	12.15	11.56	11.41
	0.16	22.30	22.04	21.65	20.68	19.18	17.89	16.07	15.11	13.71	12.71	12.14	11.99
	0.20	22.35	22.10	21.72	20.80	19.37	18.14	16.45	15.56	14.25	13.27	12.71	12.57
	0.24	22.39	22.15	21.79	20.92	19.56	18.40	16.82	16.00	14.79	13.83	13.28	13.15
	0.28	22.43	22.21	21.86	21.03	19.75	18.65	17.19	16.45	15.32	14.39	13.86	13.73
	0.32	22.47	22.26	21.94	21.15	19.93	18.90	17.57	16.90	15.86	14.95	14.43	14.31
	0.36	22.51	22.31	22.01	21.27	20.12	19.16	17.94	17.34	16.39	15.51	15.01	14.89
	0.40	22.55	22.37	22.08	21.39	20.31	19.41	18.31	17.79	16.93	16.07	15.58	15.47
	0.44	22.59	22.42	22.15	21.50	20.50	19.66	18.69	18.24	17.47	16.63	16.15	16.05
	0.48	22.63	22.47	22.22	21.62	20.69	19.91	19.06	18.69	18.00	17.19	16.73	16.63
	0.52	22.68	22.53	22.30	21.74	20.87	20.17	19.43	19.13	18.54	17.76	17.30	17.21
	0.56	22.72	22.58	22.37	21.86	21.06	20.42	19.80	19.58	19.07	18.32	17.88	17.79
	0.60	22.76	22.63	22.44	21.97	21.25	20.67	20.18	20.03	19.61	18.88	18.45	18.37
	0.64	22.80	22.69	22.51	22.09	21.44	20.92	20.55	20.48	20.15	19.44	19.02	18.95
	0.68	22.84	22.74	22.58	22.21	21.63	21.18	20.92	20.92	20.68	20.00	19.60	19.53
	0.72	22.88	22.79	22.66	22.33	21.81	21.43	21.30	21.37	21.22	20.56	20.17	20.11
	0.76	22.92	22.85	22.73	22.44	22.00	21.68	21.67	21.82	21.75	21.12	20.75	20.69
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.80	22.96	22.90	22.80	22.56	22.19	21.94	22.04	22.26	22.29	21.68	21.32	21.27
	0.84	23.01	22.96	22.87	22.68	22.38	22.19	22.42	22.71	22.83	22.24	21.89	21.85
	0.88	23.05	23.01	22.94	22.80	22.57	22.44	22.79	23.16	23.36	22.80	22.47	22.43
	0.92	23.09	23.06	23.02	22.91	22.75	22.69	23.16	23.61	23.90	23.36	23.04	23.01
	0.96	23.13	23.12	23.09	23.03	22.94	22.95	23.54	24.05	24.43	23.92	23.62	23.59
	1.00	23.17	23.17	23.16	23.15	23.13	23.20	23.91	24.50	24.97	24.48	24.19	24.17
	0.00	22.04	21.70	21.24	20.14	18.44	17.37	15.19	13.66	12.02	10.79	10.03	9.79
	0.11	22.18	21.81	21.32	20.15	18.44	17.45	15.59	14.36	12.98	11.97	11.33	11.19
	0.22	22.42	22.30	22.01	21.08	19.46	18.48	16.67	15.43	14.00	12.94	12.33	12.18
	0.33	22.64	22.58	22.49	21.99	20.81	20.03	18.65	17.70	16.46	15.46	14.86	14.71
COILSET SURFACE TEMPERATURE (°C)	0.44	22.77	22.71	22.66	22.35	21.46	20.84	19.82	19.11	18.05	17.16	16.61	16.53
	0.56	22.83	22.79	22.75	22.60	22.12	21.73	21.10	20.64	19.77	19.04	18.56	18.48
	0.67	22.88	22.86	22.85	22.78	22.64	22.49	22.25	22.02	21.46	20.71	20.28	20.21
	0.78	22.97	22.96	22.96	22.91	23.08	23.31	23.85	24.08	23.87	23.41	23.14	23.13
	0.89	23.06	23.05	23.04	23.02	23.38	23.87	24.97	25.52	25.62	25.34	25.22	25.19
	1.00	22.97	22.96	22.96	22.93	23.00	23.25	24.01	24.56	24.72	24.24	24.00	23.97
	0.00	22.14	21.83	21.36	20.21	18.43	16.88	14.58	13.32	11.57	10.47	9.84	9.67
	0.04	21.74	21.52	21.09	20.16	18.59	17.77	16.08	14.93	13.68	12.80	12.23	12.00
	0.08	21.78	21.63	21.28	20.36	18.71	17.82	16.06	14.86	13.51	12.60	12.00	11.78
	0.12	21.86	21.73	21.49	20.73	19.19	18.34	16.63	15.50	14.20	13.33	12.74	12.57
	0.16	21.90	21.79	21.63	20.95	19.39	18.53	16.74	15.55	14.15	13.25	12.63	12.36
	0.20	22.01	21.90	21.78	21.21	19.78	18.99	17.34	16.25	14.89	14.00	13.41	13.18
	0.24	22.06	21.97	21.86	21.44	20.16	19.44	17.94	16.93	15.65	14.77	14.22	13.98
	0.28	22.07	22.00	21.92	21.61	20.48	19.80	18.39	17.43	16.18	15.33	14.76	14.56
	0.32	22.12	22.04	21.98	21.76	20.76	20.13	18.84	17.94	16.75	15.90	15.38	15.12
	0.36	22.16	22.08	22.00	21.88	21.03	20.51	19.34	18.54	17.40	16.57	16.04	15.85
	0.40	22.21	22.12	22.06	21.97	21.28	20.82	19.75	18.98	17.90	17.09	16.56	16.40
	0.44	22.25	22.17	22.12	22.07	21.52	21.12	20.25	19.59	18.55	17.76	17.27	17.09
	0.48	22.25	22.21	22.15	22.13	21.71	21.42	20.65	20.07	19.14	18.36	17.87	17.74
	0.52	22.27	22.24	22.19	22.17	21.90	21.69	21.08	20.58	19.75	18.98	18.56	18.41
	0.56	22.32	22.28	22.26	22.25	22.06	21.97	21.53	21.13	20.38	19.68	19.28	19.10
	0.60	22.34	22.29	22.28	22.27	22.19	22.21	21.93	21.62	20.98	20.29	19.91	19.80
	0.64	22.34	22.33	22.30	22.33	22.34	22.43	22.35	22.16	21.62	20.99	20.64	20.45
	0.68	22.36	22.33	22.31	22.34	22.42	22.59	22.71	22.62	22.14	21.53	21.24	21.05
	0.72	22.40	22.35	22.35	22.38	22.51	22.79	23.08	23.10	22.74	22.18	21.90	21.74
	0.76	22.40	22.39	22.36	22.42	22.59	22.95	23.45	23.55	23.33	22.82	22.54	22.39
	0.80	22.41	22.39	22.37	22.42	22.63	23.08	23.78	23.98	23.88	23.41	23.15	23.01
	0.84	22.43	22.41	22.39	22.46	22.72	23.22	24.13	24.47	24.45	24.07	23.86	23.68
	0.88	22.46	22.42	22.43	22.51	22.78	23.33	24.40	24.86	24.95	24.58	24.41	24.24
	0.92	22.48	22.44	22.43	22.51	22.77	23.35	24.53	25.12	25.29	24.99	24.80	24.68
	0.96	22.43	22.38	22.38	22.45	22.66	23.14	24.29	24.91	25.22	25.07	24.97	24.88
	1.00	23.17	23.17	23.16	23.15	23.13	23.20	23.91	24.50	24.97	24.48	24.19	24.17

Table F10: R3-60 mains-side temperature values at 9LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	21.81	21.32	20.82	19.73	17.76	16.48	14.84	13.48	11.91	10.75	10.08	9.86
	0.04	21.85	21.38	20.90	19.85	17.97	16.74	15.20	13.93	12.45	11.32	10.67	10.45
	0.08	21.89	21.44	20.98	19.97	18.17	17.01	15.55	14.38	12.99	11.89	11.25	11.05
	0.12	21.92	21.49	21.05	20.10	18.38	17.27	15.91	14.82	13.53	12.46	11.84	11.64
	0.16	21.96	21.55	21.13	20.22	18.58	17.54	16.27	15.27	14.06	13.03	12.42	12.23
	0.20	22.00	21.61	21.21	20.34	18.79	17.80	16.63	15.72	14.60	13.60	13.01	12.83
	0.24	22.04	21.67	21.29	20.46	18.99	18.07	16.98	16.17	15.14	14.17	13.59	13.42
	0.28	22.07	21.72	21.37	20.59	19.20	18.33	17.34	16.61	15.68	14.74	14.18	14.01
	0.32	22.11	21.78	21.44	20.71	19.40	18.60	17.70	17.06	16.22	15.31	14.76	14.61
	0.36	22.15	21.84	21.52	20.83	19.61	18.86	18.05	17.51	16.76	15.88	15.35	15.20
	0.40	22.19	21.90	21.60	20.95	19.81	19.13	18.41	17.96	17.29	16.45	15.93	15.79
	0.44	22.22	21.95	21.68	21.08	20.02	19.39	18.77	18.40	17.83	17.02	16.52	16.39
	0.48	22.26	22.01	21.76	21.20	20.22	19.66	19.13	18.85	18.37	17.59	17.10	16.98
	0.52	22.30	22.07	21.83	21.32	20.43	19.92	19.48	19.30	18.91	18.17	17.69	17.57
	0.56	22.34	22.13	21.91	21.44	20.63	20.19	19.84	19.75	19.45	18.74	18.27	18.16
	0.60	22.37	22.18	21.99	21.57	20.84	20.45	20.20	20.19	19.99	19.31	18.86	18.76
	0.64	22.41	22.24	22.07	21.69	21.04	20.72	20.56	20.64	20.52	19.88	19.44	19.35
	0.68	22.45	22.30	22.15	21.81	21.25	20.98	20.91	21.09	21.06	20.45	20.03	19.94
	0.72	22.49	22.36	22.22	21.93	21.45	21.25	21.27	21.54	21.60	21.02	20.61	20.54
	0.76	22.52	22.41	22.30	22.06	21.66	21.51	21.63	21.98	22.14	21.59	21.20	21.13
	0.80	22.56	22.47	22.38	22.18	21.86	21.78	21.98	22.43	22.68	22.16	21.78	21.72
	0.84	22.60	22.53	22.46	22.30	22.07	22.04	22.34	22.88	23.22	22.73	22.37	22.32
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.88	22.64	22.59	22.54	22.42	22.27	22.31	22.70	23.33	23.75	23.30	22.95	22.91
	0.92	22.67	22.64	22.61	22.55	22.48	22.57	23.06	23.77	24.29	23.87	23.54	23.50
	0.96	22.71	22.70	22.69	22.67	22.68	22.84	23.41	24.22	24.83	24.44	24.12	24.10
	1.00	22.75	22.76	22.77	22.79	22.89	23.10	23.77	24.67	25.37	25.01	24.71	24.69
	0.00	21.80	21.39	20.92	19.91	18.44	17.50	15.51	14.09	12.38	11.05	10.23	9.92
	0.11	21.91	21.46	20.96	19.92	18.41	17.58	15.92	14.78	13.37	12.28	11.61	11.42
	0.22	22.36	22.12	21.76	20.87	19.45	18.62	17.04	15.89	14.47	13.31	12.64	12.46
	0.33	22.53	22.48	22.35	21.84	20.81	20.14	18.99	18.19	17.01	15.90	15.23	15.11
	0.44	22.59	22.58	22.53	22.20	21.42	20.90	20.12	19.54	18.62	17.66	17.07	16.96
	0.56	22.60	22.60	22.59	22.50	22.09	21.77	21.38	21.06	20.37	19.51	19.07	18.96
COILSET SURFACE TEMPERATURE (°C)	0.67	22.61	22.61	22.62	22.62	22.58	22.45	22.37	22.35	21.97	21.19	20.79	20.70
	0.78	22.67	22.68	22.70	22.77	23.02	23.21	23.99	24.40	24.44	23.93	23.66	23.69
	0.89	22.73	22.75	22.78	22.92	23.34	23.78	25.16	25.88	26.23	25.93	25.80	25.85
	1.00	22.57	22.65	22.59	22.65	22.81	23.04	23.96	24.65	25.14	24.72	24.49	24.45
	0.00	21.81	21.32	20.82	19.73	17.76	16.48	14.84	13.48	11.91	10.75	10.08	9.86
	0.04	21.78	21.23	20.70	19.62	18.29	17.49	16.21	15.09	13.90	12.89	12.25	12.05
	0.08	21.95	21.43	20.93	19.86	18.55	17.72	16.38	15.31	14.05	13.06	12.42	12.26
	0.12	22.14	21.62	21.18	20.19	18.91	18.10	16.85	15.78	14.53	13.59	12.94	12.74
	0.16	22.18	21.74	21.37	20.41	19.11	18.28	16.96	15.85	14.57	13.52	12.89	12.71
	0.20	22.21	21.84	21.55	20.71	19.47	18.68	17.48	16.47	15.23	14.17	13.56	13.43
	0.24	22.27	21.93	21.71	21.00	19.92	19.19	18.18	17.30	16.11	15.13	14.57	14.39
	0.28	22.29	21.98	21.81	21.20	20.23	19.51	18.60	17.77	16.67	15.67	15.11	14.99
	0.32	22.29	21.99	21.88	21.37	20.51	19.86	19.03	18.27	17.22	16.25	15.67	15.56
	0.36	22.35	22.04	21.95	21.56	20.82	20.23	19.52	18.85	17.86	16.88	16.37	16.25
	0.40	22.40	22.06	21.96	21.68	21.05	20.53	19.97	19.38	18.44	17.42	16.99	16.82
	0.44	22.35	22.06	21.98	21.78	21.29	20.84	20.40	19.91	19.06	18.10	17.66	17.52
	0.48	22.40	22.08	22.04	21.86	21.51	21.12	20.83	20.43	19.65	18.72	18.32	18.14
	0.52	22.39	22.10	22.05	21.92	21.70	21.38	21.23	20.90	20.21	19.31	18.90	18.73
	0.56	22.43	22.12	22.05	21.98	21.89	21.64	21.64	21.41	20.83	19.96	19.60	19.43
	0.60	22.42	22.14	22.08	22.02	22.05	21.88	22.07	21.96	21.48	20.64	20.30	20.17
	0.64	22.41	22.13	22.08	22.03	22.16	22.05	22.42	22.42	22.07	21.28	20.98	20.87
	0.68	22.46	22.15	22.10	22.05	22.27	22.27	22.81	22.88	22.65	21.91	21.65	21.52
	0.72	22.43	22.13	22.09	22.07	22.36	22.43	23.19	23.39	23.24	22.52	22.32	22.21
	0.76	22.48	22.15	22.10	22.09	22.43	22.57	23.50	23.83	23.79	23.13	22.92	22.87
	0.80	22.39	22.12	22.08	22.09	22.48	22.69	23.80	24.25	24.32	23.73	23.56	23.53
	0.84	22.46	22.15	22.12	22.13	22.56	22.84	24.15	24.70	24.90	24.36	24.22	24.21
	0.88	22.43	22.15	22.09	22.11	22.57	22.88	24.38	25.04	25.37	24.87	24.76	24.78
	0.92	22.46	22.14	22.09	22.11	22.60	22.99	24.60	25.35	25.76	25.36	25.22	25.29
	0.96	22.44	22.14	22.10	22.09	22.56	22.87	24.57	25.42	25.94	25.36	25.59	25.63
	1.00	22.75	22.76	22.77	22.79	22.89	23.10	23.77	24.67	25.37	25.01	24.71	24.69

Table F11: R3-60 mains-side temperature values at 7LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.15	22.06	21.62	21.30	19.70	18.93	16.50	15.21	13.03	11.42	10.43	10.12
	0.04	22.17	22.08	21.66	21.35	19.82	19.08	16.76	15.55	13.53	12.01	11.06	10.76
	0.08	22.19	22.10	21.70	21.40	19.93	19.23	17.02	15.89	14.04	12.61	11.68	11.40
	0.12	22.20	22.12	21.74	21.46	20.05	19.37	17.28	16.24	14.54	13.20	12.31	12.04
	0.16	22.22	22.14	21.78	21.51	20.17	19.52	17.54	16.58	15.04	13.79	12.93	12.68
	0.20	22.24	22.17	21.82	21.56	20.28	19.67	17.80	16.92	15.55	14.39	13.56	13.31
	0.24	22.26	22.19	21.86	21.61	20.40	19.82	18.06	17.26	16.05	14.98	14.18	13.95
	0.28	22.28	22.21	21.89	21.66	20.52	19.97	18.33	17.61	16.55	15.58	14.81	14.59
	0.32	22.29	22.23	21.93	21.72	20.63	20.11	18.59	17.95	17.06	16.17	15.43	15.23
	0.36	22.31	22.25	21.97	21.77	20.75	20.26	18.85	18.29	17.56	16.76	16.06	15.87
	0.40	22.33	22.27	22.01	21.82	20.87	20.41	19.11	18.63	18.06	17.36	16.68	16.51
	0.44	22.35	22.29	22.05	21.87	20.98	20.56	19.37	18.98	18.57	17.95	17.31	17.15
	0.48	22.37	22.31	22.09	21.92	21.10	20.71	19.63	19.32	19.07	18.54	17.93	17.79
	0.52	22.38	22.34	22.13	21.98	21.22	20.85	19.89	19.66	19.57	19.14	18.56	18.42
	0.56	22.40	22.36	22.17	22.03	21.34	21.00	20.15	20.00	20.07	19.73	19.18	19.06
	0.60	22.42	22.38	22.21	22.08	21.45	21.15	20.41	20.35	20.58	20.32	19.81	19.70
	0.64	22.44	22.40	22.25	22.13	21.57	21.30	20.67	20.69	21.08	20.92	20.43	20.34
	0.68	22.46	22.42	22.29	22.18	21.69	21.45	20.93	21.03	21.58	21.51	21.06	20.98
	0.72	22.47	22.44	22.33	22.24	21.80	21.59	21.19	21.37	22.09	22.10	21.68	21.62
	0.76	22.49	22.46	22.36	22.29	21.92	21.74	21.46	21.72	22.59	22.70	22.31	22.26
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.80	22.51	22.48	22.40	22.34	22.04	21.89	21.72	22.06	23.09	23.29	22.93	22.90
	0.84	22.53	22.51	22.44	22.39	22.15	22.04	21.98	22.40	23.60	23.89	23.56	23.53
	0.88	22.55	22.53	22.48	22.44	22.27	22.19	22.24	22.74	24.10	24.48	24.18	24.17
	0.92	22.56	22.55	22.52	22.50	22.39	22.33	22.50	23.09	24.60	25.07	24.81	24.81
	0.96	22.58	22.57	22.56	22.55	22.50	22.48	22.76	23.43	25.11	25.67	25.43	25.45
	1.00	22.60	22.59	22.60	22.60	22.62	22.63	23.02	23.77	25.61	26.26	26.06	26.09
	0.00	22.12	22.00	21.82	21.24	20.17	19.41	17.58	16.02	13.81	11.94	10.75	10.34
	0.11	22.20	22.10	21.92	21.30	20.16	19.40	17.68	16.40	14.60	13.09	12.10	11.85
	0.22	22.27	22.25	22.21	21.93	21.07	20.39	18.81	17.61	15.93	14.41	13.42	13.14
	0.33	22.35	22.31	22.31	22.26	21.84	21.44	20.33	19.55	18.37	17.18	16.24	16.01
COILSET SURFACE TEMPERATURE (°C)	0.44	22.42	22.39	22.39	22.36	22.15	21.88	21.18	20.72	19.90	18.94	18.17	18.00
	0.56	22.43	22.40	22.40	22.37	22.33	22.25	22.01	21.92	21.56	20.90	20.23	20.10
	0.67	22.44	22.42	22.42	22.41	22.41	22.45	22.60	22.88	23.07	22.67	22.15	22.08
	0.78	22.45	22.45	22.47	22.47	22.50	22.66	23.47	24.40	25.27	25.35	25.05	25.08
	0.89	22.51	22.50	22.51	22.51	22.61	22.87	24.11	25.48	26.84	27.27	27.19	27.29
	1.00	22.51	22.51	22.50	22.51	22.54	22.61	23.17	24.15	25.64	26.13	25.93	25.96
	0.00	22.15	22.06	21.62	21.30	19.70	18.93	16.50	15.21	13.03	11.42	10.43	10.12
	0.04	21.78	21.76	21.61	21.07	19.92	19.21	17.48	16.34	14.78	12.96	12.12	11.85
	0.08	21.83	21.81	21.73	21.32	20.35	19.73	18.13	17.10	15.61	13.93	13.14	12.82
	0.12	21.82	21.81	21.74	21.43	20.55	19.95	18.37	17.34	15.90	14.22	13.45	13.19
	0.16	21.82	21.82	21.78	21.55	20.71	20.08	18.43	17.30	15.74	13.90	13.01	12.69
	0.20	21.84	21.83	21.79	21.65	20.96	20.41	18.88	17.87	16.43	14.69	13.87	13.52
	0.24	21.91	21.90	21.86	21.75	21.21	20.77	19.44	18.59	17.38	15.72	14.99	14.67
	0.28	21.93	21.92	21.87	21.81	21.38	21.01	19.79	19.02	17.88	16.24	15.50	15.22
	0.32	21.92	21.90	21.83	21.77	21.46	21.14	20.05	19.35	18.31	16.75	16.03	15.80
	0.36	21.91	21.88	21.83	21.77	21.53	21.29	20.34	19.75	18.86	17.45	16.76	16.50
	0.40	21.96	21.94	21.88	21.81	21.62	21.48	20.68	20.19	19.40	18.01	17.33	17.10
	0.44	21.99	21.97	21.91	21.83	21.67	21.57	20.95	20.62	20.03	18.77	18.11	17.95
	0.48	22.05	22.02	21.96	21.87	21.77	21.73	21.27	21.08	20.62	19.43	18.81	18.61
	0.52	22.00	22.00	21.94	21.87	21.79	21.82	21.50	21.46	21.15	20.08	19.52	19.36
	0.56	22.00	22.01	21.95	21.88	21.79	21.83	21.70	21.81	21.68	20.72	20.20	20.10
	0.60	22.02	22.02	22.00	21.94	21.84	21.92	21.96	22.21	22.23	21.37	20.89	20.82
	0.64	22.05	22.07	22.02	21.98	21.89	22.00	22.20	22.59	22.83	22.07	21.67	21.55
	0.68	22.04	22.06	22.02	21.97	21.89	22.00	22.36	22.91	23.30	22.71	22.31	22.17
	0.72	22.04	22.05	22.02	21.98	21.89	22.02	22.50	23.24	23.83	23.35	23.01	22.91
	0.76	22.05	22.03	22.02	21.97	21.89	22.05	22.65	23.54	24.36	24.01	23.73	23.68
	0.80	22.09	22.08	22.05	22.02	21.95	22.11	22.84	23.91	24.92	24.66	24.47	24.40
	0.84	22.07	22.08	22.06	22.02	21.96	22.15	23.00	24.24	25.48	25.39	25.26	25.18
	0.88	22.09	22.08	22.06	22.04	22.00	22.20	23.12	24.53	25.95	25.98	25.88	25.83
	0.92	22.08	22.08	22.06	22.06	22.01	22.21	23.19	24.72	26.34	26.44	26.36	26.43
	0.96	22.07	22.06	22.06	22.04	21.99	22.17	23.12	24.64	26.29	26.52	26.58	26.66
	1.00	22.60	22.59	22.60	22.60	22.62	22.63	23.02	23.77	25.61	26.26	26.06	26.09

Table F12: R3-60 mains-side temperature values at 5.5LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	21.09	20.93	20.54	20.08	19.19	18.54	17.08	15.71	14.15	12.34	10.97	10.56
	0.04	21.11	20.95	20.58	20.14	19.28	18.66	17.28	16.00	14.58	12.92	11.62	11.23
	0.08	21.12	20.97	20.62	20.20	19.38	18.78	17.47	16.30	15.02	13.51	12.27	11.90
	0.12	21.14	21.00	20.66	20.25	19.47	18.91	17.67	16.59	15.45	14.09	12.92	12.58
	0.16	21.15	21.02	20.69	20.31	19.57	19.03	17.87	16.89	15.88	14.68	13.57	13.25
	0.20	21.17	21.04	20.73	20.37	19.66	19.15	18.06	17.18	16.31	15.26	14.22	13.92
	0.24	21.19	21.06	20.77	20.43	19.76	19.27	18.26	17.48	16.75	15.84	14.87	14.59
	0.28	21.20	21.09	20.81	20.48	19.85	19.40	18.46	17.77	17.18	16.43	15.52	15.26
	0.32	21.22	21.11	20.85	20.54	19.95	19.52	18.65	18.07	17.61	17.01	16.17	15.94
	0.36	21.23	21.13	20.89	20.60	20.04	19.64	18.85	18.36	18.05	17.60	16.82	16.61
	0.40	21.25	21.15	20.92	20.66	20.13	19.76	19.05	18.65	18.48	18.18	17.47	17.28
	0.44	21.27	21.18	20.96	20.71	20.23	19.89	19.24	18.95	18.91	18.76	18.12	17.95
	0.48	21.28	21.20	21.00	20.77	20.32	20.01	19.44	19.24	19.34	19.35	18.77	18.62
	0.52	21.30	21.22	21.04	20.83	20.42	20.13	19.64	19.54	19.78	19.93	19.42	19.30
	0.56	21.31	21.24	21.08	20.89	20.51	20.25	19.84	19.83	20.21	20.52	20.07	19.97
	0.60	21.33	21.27	21.12	20.94	20.61	20.38	20.03	20.13	20.64	21.10	20.72	20.64
	0.64	21.35	21.29	21.15	21.00	20.70	20.50	20.23	20.42	21.07	21.68	21.37	21.31
	0.68	21.36	21.31	21.19	21.06	20.79	20.62	20.43	20.71	21.51	22.27	22.02	21.98
	0.72	21.38	21.33	21.23	21.12	20.89	20.74	20.62	21.01	21.94	22.85	22.67	22.66
	0.76	21.39	21.36	21.27	21.17	20.98	20.87	20.82	21.30	22.37	23.44	23.32	23.33
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.80	21.41	21.38	21.31	21.23	21.08	20.99	21.02	21.60	22.81	24.02	23.97	24.00
	0.84	21.43	21.40	21.35	21.29	21.17	21.11	21.21	21.89	23.24	24.60	24.62	24.67
	0.88	21.44	21.42	21.38	21.35	21.27	21.23	21.41	22.19	23.67	25.19	25.27	25.34
	0.92	21.46	21.45	21.42	21.40	21.36	21.36	21.61	22.48	24.10	25.77	25.92	26.02
	0.96	21.47	21.47	21.46	21.46	21.46	21.48	21.80	22.78	24.54	26.36	26.57	26.69
	1.00	21.49	21.49	21.50	21.52	21.55	21.60	22.00	23.07	24.97	26.94	27.22	27.36
	0.00	21.16	21.05	20.89	20.50	19.83	19.33	18.11	16.97	15.11	12.98	11.35	10.81
	0.11	21.21	21.09	20.94	20.50	19.76	19.24	18.12	17.11	15.63	13.88	12.60	12.19
	0.22	21.38	21.35	21.29	21.08	20.55	20.14	19.18	18.33	17.04	15.41	14.15	13.75
	0.33	21.41	21.42	21.41	21.35	21.12	20.92	20.38	19.90	19.15	18.01	16.95	16.59
COILSET SURFACE TEMPERATURE (°C)	0.44	21.46	21.46	21.46	21.45	21.36	21.27	21.05	20.87	20.54	19.78	18.93	18.68
	0.56	21.43	21.44	21.44	21.44	21.45	21.47	21.65	21.83	21.99	21.70	21.07	20.86
	0.67	21.42	21.43	21.44	21.45	21.49	21.57	21.98	22.55	23.33	23.69	23.36	23.28
	0.78	21.42	21.43	21.44	21.46	21.54	21.72	22.66	23.72	25.14	26.15	26.18	26.18
	0.89	21.44	21.45	21.47	21.50	21.65	21.92	23.30	24.75	26.71	28.23	28.44	28.60
	1.00	21.47	21.48	21.49	21.49	21.54	21.65	22.24	23.25	25.16	26.90	27.14	27.23
	0.00	21.09	20.93	20.54	20.08	19.19	18.54	17.08	15.71	14.15	12.34	10.97	10.56
	0.04	20.45	20.32	20.22	19.86	19.10	18.66	17.55	16.73	15.52	14.09	12.73	12.37
	0.08	20.59	20.48	20.38	20.08	19.34	18.93	17.80	17.00	15.74	14.32	12.86	12.50
	0.12	20.66	20.59	20.56	20.29	19.65	19.27	18.30	17.54	16.43	15.13	13.74	13.39
	0.16	20.60	20.56	20.55	20.34	19.75	19.37	18.39	17.63	16.47	15.08	13.63	13.30
	0.20	20.62	20.60	20.60	20.46	19.93	19.60	18.70	18.06	16.99	15.71	14.26	13.91
	0.24	20.66	20.62	20.68	20.57	20.15	19.88	19.15	18.63	17.79	16.65	15.35	15.03
	0.28	20.70	20.67	20.72	20.67	20.32	20.13	19.50	19.08	18.32	17.29	16.06	15.81
	0.32	20.67	20.64	20.70	20.67	20.41	20.24	19.76	19.40	18.80	17.85	16.63	16.37
	0.36	20.64	20.64	20.69	20.69	20.49	20.37	20.00	19.78	19.33	18.57	17.35	17.14
	0.40	20.66	20.64	20.72	20.73	20.56	20.50	20.26	20.17	19.86	19.18	18.04	17.81
	0.44	20.66	20.66	20.72	20.73	20.62	20.62	20.50	20.53	20.38	19.89	18.82	18.63
	0.48	20.69	20.67	20.73	20.76	20.67	20.72	20.75	20.90	20.91	20.53	19.47	19.32
	0.52	20.65	20.64	20.70	20.73	20.67	20.77	20.91	21.20	21.39	21.20	20.30	20.16
	0.56	20.69	20.68	20.73	20.78	20.74	20.86	21.12	21.53	21.89	21.83	21.00	20.89
	0.60	20.70	20.69	20.76	20.80	20.77	20.93	21.32	21.85	22.40	22.50	21.76	21.74
	0.64	20.72	20.71	20.78	20.81	20.99	21.50	22.17	22.89	23.20	23.20	22.46	22.47
	0.68	20.70	20.68	20.75	20.80	20.80	21.01	21.61	22.40	23.33	23.78	23.18	23.22
	0.72	20.70	20.69	20.76	20.81	20.81	21.05	21.77	22.72	23.80	24.42	23.93	23.96
	0.76	20.71	20.70	20.77	20.82	20.85	21.10	21.90	22.97	24.22	25.05	24.68	24.73
	0.80	20.68	20.66	20.76	20.80	20.86	21.14	22.03	23.22	24.67	25.67	25.42	25.47
	0.84	20.68	20.67	20.75	20.80	20.87	21.18	22.19	23.49	25.12	26.31	26.18	26.28
	0.88	20.66	20.67	20.74	20.80	20.89	21.23	22.30	23.70	25.52	26.89	26.79	26.91
	0.92	20.68	20.67	20.74	20.80	20.91	21.26	22.38	23.89	25.85	27.38	27.39	27.57
	0.96	20.65	20.65	20.73	20.79	20.89	21.24	22.39	23.86	25.83	27.42	27.55	27.70
	1.00	21.49	21.49	21.50	21.52	21.55	21.60	22.00	23.07	24.97	26.94	27.22	27.36

Table F13: R4-36 mains-side temperature values at 14LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.26	22.28	22.26	21.12	18.57	17.04	13.74	12.28	11.01	10.16	9.80	9.69
	0.07	22.26	22.28	22.26	21.20	18.82	17.40	14.29	12.88	11.62	10.75	10.40	10.30
	0.13	22.27	22.28	22.26	21.28	19.07	17.75	14.84	13.48	12.23	11.34	11.00	10.91
	0.20	22.27	22.28	22.26	21.35	19.32	18.11	15.39	14.08	12.83	11.93	11.61	11.52
	0.27	22.28	22.29	22.27	21.43	19.57	18.46	15.94	14.67	13.44	12.52	12.21	12.13
	0.33	22.28	22.29	22.27	21.51	19.82	18.82	16.49	15.27	14.05	13.11	12.81	12.74
	0.40	22.28	22.29	22.27	21.59	20.07	19.18	17.04	15.87	14.66	13.70	13.41	13.35
	0.47	22.29	22.29	22.27	21.67	20.32	19.53	17.59	16.47	15.27	14.29	14.01	13.96
	0.53	22.29	22.29	22.27	21.74	20.57	19.89	18.15	17.07	15.87	14.87	14.62	14.56
	0.60	22.30	22.29	22.27	21.82	20.82	20.24	18.70	17.67	16.48	15.46	15.22	15.17
	0.67	22.30	22.29	22.27	21.90	21.07	20.60	19.25	18.27	17.09	16.05	15.82	15.78
	0.73	22.30	22.29	22.27	21.98	21.32	20.96	19.80	18.87	17.70	16.64	16.42	16.39
	0.80	22.31	22.30	22.28	22.06	21.57	21.31	20.35	19.46	18.31	17.23	17.02	17.00
	0.87	22.31	22.30	22.28	22.13	21.82	21.67	20.90	20.06	18.91	17.82	17.63	17.61
	0.93	22.32	22.30	22.28	22.21	22.07	22.02	21.45	20.66	19.52	18.41	18.23	18.22
	1.00	22.32	22.30	22.28	22.29	22.32	22.38	22.00	21.26	20.13	19.00	18.83	18.83
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.14	22.13	21.92	20.37	17.94	16.55	14.04	12.65	11.27	10.34	9.81	9.68
	0.11	22.21	22.20	22.10	20.62	18.03	16.60	14.24	12.95	11.72	10.91	10.53	10.42
	0.22	22.22	22.21	22.14	20.75	18.36	17.15	15.33	14.35	13.24	12.52	12.26	12.21
	0.33	22.19	22.20	22.21	21.67	19.47	18.24	16.34	15.35	14.12	13.38	13.14	13.11
	0.44	22.21	22.19	22.22	22.11	20.41	19.25	17.35	16.30	15.00	14.29	14.06	13.98
	0.56	22.15	22.14	22.16	22.20	21.30	20.57	19.12	18.35	17.11	16.50	16.34	16.29
	0.67	22.12	22.12	22.14	22.19	21.90	21.47	20.41	19.79	18.69	18.14	18.00	18.02
	0.78	22.11	22.13	22.14	22.20	22.28	22.18	21.46	20.96	20.04	19.45	19.36	19.41
	0.89	22.14	22.14	22.17	22.22	22.40	22.49	22.14	21.79	20.96	20.36	20.30	20.34
	1.00	22.12	22.10	22.12	22.15	22.27	22.25	21.55	20.90	19.83	18.93	18.76	18.75
COILSET SURFACE TEMPERATURE (°C)	0.00	22.26	22.28	22.26	21.12	18.57	17.04	13.74	12.28	11.01	10.16	9.80	9.69
	0.07	21.48	21.51	21.50	20.61	18.11	16.79	14.80	13.66	12.47	11.84	11.46	11.45
	0.13	21.46	21.50	21.52	20.98	18.40	16.98	14.87	13.69	12.41	11.75	11.41	11.39
	0.20	21.43	21.46	21.48	21.27	19.02	17.66	15.63	14.51	13.25	12.64	12.35	12.39
	0.27	21.43	21.43	21.46	21.41	19.43	18.05	16.00	14.86	13.53	12.90	12.59	12.65
	0.33	21.43	21.42	21.44	21.47	19.90	18.58	16.65	15.56	14.27	13.65	13.34	13.38
	0.40	21.42	21.42	21.42	21.49	20.40	19.26	17.47	16.46	15.19	14.59	14.30	14.33
	0.47	21.39	21.39	21.40	21.47	20.76	19.76	18.12	17.14	15.87	15.28	15.04	15.06
	0.53	21.38	21.38	21.39	21.47	21.11	20.29	18.82	17.92	16.66	16.07	15.87	15.86
	0.60	21.37	21.38	21.40	21.47	21.37	20.72	19.45	18.61	17.40	16.81	16.61	16.63
	0.67	21.31	21.32	21.35	21.40	21.48	21.07	20.05	19.32	18.20	17.63	17.43	17.49
	0.73	21.30	21.32	21.35	21.41	21.61	21.44	20.70	20.09	19.04	18.48	18.29	18.33
	0.80	21.31	21.32	21.36	21.42	21.69	21.74	21.20	20.59	19.54	18.93	18.79	18.83
	0.87	21.34	21.35	21.40	21.46	21.80	22.05	21.78	21.27	20.27	19.63	19.50	19.55
	0.93	21.43	21.44	21.46	21.54	21.77	22.13	22.01	21.52	20.54	19.86	19.73	19.76
	1.00	22.32	22.30	22.28	22.29	22.32	22.38	22.00	21.26	20.13	19.00	18.83	18.83

Table F14: R4-36 mains-side temperature values at 12LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.36	21.61	20.98	18.92	16.60	15.69	14.00	12.57	11.48	10.66	10.26	10.13
	0.07	22.37	21.67	21.09	19.17	17.01	16.17	14.57	13.20	12.12	11.29	10.90	10.77
	0.13	22.39	21.74	21.19	19.41	17.42	16.64	15.15	13.83	12.77	11.92	11.54	11.41
	0.20	22.40	21.80	21.30	19.66	17.83	17.12	15.72	14.46	13.41	12.55	12.18	12.05
	0.27	22.42	21.87	21.41	19.90	18.25	17.60	16.30	15.10	14.05	13.19	12.81	12.69
	0.33	22.43	21.93	21.52	20.15	18.66	18.07	16.87	15.73	14.69	13.82	13.45	13.33
	0.40	22.44	22.00	21.62	20.40	19.07	18.55	17.44	16.36	15.34	14.45	14.09	13.97
	0.47	22.46	22.06	21.73	20.64	19.48	19.03	18.02	16.99	15.98	15.08	14.73	14.61
	0.53	22.47	22.13	21.84	20.89	19.89	19.50	18.59	17.62	16.62	15.71	15.37	15.25
	0.60	22.49	22.19	21.95	21.13	20.30	19.98	19.17	18.25	17.26	16.34	16.01	15.89
	0.67	22.50	22.26	22.05	21.38	20.71	20.46	19.74	18.88	17.91	16.97	16.65	16.53
	0.73	22.51	22.32	22.16	21.63	21.12	20.93	20.31	19.51	18.55	17.60	17.29	17.17
	0.80	22.53	22.39	22.27	21.87	21.54	21.41	20.89	20.15	19.19	18.24	17.92	17.81
	0.87	22.54	22.45	22.38	22.12	21.95	21.89	21.46	20.78	19.83	18.87	18.56	18.45
	0.93	22.56	22.52	22.48	22.36	22.36	22.36	22.04	21.41	20.48	19.50	19.20	19.09
	1.00	22.57	22.58	22.59	22.61	22.77	22.84	22.61	22.04	21.12	20.13	19.84	19.73
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	21.83	21.28	20.64	19.30	17.45	16.37	14.34	13.07	11.75	10.80	10.36	10.13
	0.11	22.09	21.57	20.92	19.51	17.61	16.54	14.63	13.46	12.31	11.53	11.11	10.90
	0.22	22.17	21.68	21.07	19.77	18.12	17.35	15.82	14.91	14.08	13.53	13.06	12.72
	0.33	22.32	22.22	21.85	20.79	19.16	18.37	16.84	15.92	15.06	14.55	14.06	13.67
	0.44	22.40	22.39	22.29	21.59	20.18	19.41	17.92	16.97	16.03	15.51	15.03	14.66
	0.56	22.42	22.44	22.42	22.16	21.38	20.90	19.80	19.08	18.39	17.94	17.51	16.99
	0.67	22.46	22.48	22.48	22.51	22.24	21.99	21.22	20.63	19.99	19.53	19.21	18.71
	0.78	22.52	22.53	22.53	22.66	22.84	22.80	22.37	21.96	21.31	20.85	20.61	20.19
	0.89	22.59	22.62	22.61	22.73	23.05	23.15	23.13	22.85	22.19	21.69	21.47	21.34
	1.00	22.38	22.40	22.40	22.45	22.64	22.63	22.27	21.75	20.83	20.01	19.80	19.62
COILSET SURFACE TEMPERATURE (°C)	0.00	22.36	21.61	20.98	18.92	16.60	15.69	14.00	12.57	11.48	10.66	10.26	10.13
	0.07	21.44	20.95	20.33	18.99	17.29	16.42	15.01	14.01	13.03	12.38	12.17	12.02
	0.13	21.56	21.24	20.67	19.34	17.55	16.64	15.21	14.16	13.11	12.42	12.25	12.12
	0.20	21.62	21.50	21.09	19.91	18.25	17.37	16.03	15.03	13.99	13.36	13.20	13.05
	0.27	21.64	21.64	21.37	20.32	18.72	17.83	16.53	15.53	14.46	13.79	13.63	13.55
	0.33	21.62	21.63	21.54	20.70	19.21	18.38	17.12	16.15	15.09	14.42	14.25	14.17
	0.40	21.65	21.67	21.67	21.12	19.86	19.11	17.98	17.06	16.01	15.37	15.21	15.08
	0.47	21.67	21.70	21.74	21.43	20.40	19.71	18.68	17.79	16.73	16.09	15.93	15.82
	0.53	21.69	21.73	21.78	21.70	20.95	20.38	19.50	18.67	17.62	16.98	16.88	16.75
	0.60	21.72	21.76	21.82	21.87	21.39	20.91	20.18	19.41	18.40	17.79	17.69	17.58
	0.67	21.72	21.76	21.83	21.95	21.76	21.41	20.84	20.16	19.21	18.64	18.59	18.47
	0.73	21.73	21.76	21.84	21.98	22.05	21.81	21.42	20.82	19.92	19.38	19.35	19.26
	0.80	21.75	21.80	21.87	22.06	22.38	22.27	22.03	21.49	20.62	20.11	20.07	19.92
	0.87	21.80	21.85	21.92	22.10	22.59	22.62	22.54	22.05	21.20	20.69	20.66	20.51
	0.93	21.81	21.87	21.94	22.08	22.70	22.86	22.98	22.57	21.81	21.30	21.28	21.16
	1.00	22.57	22.58	22.59	22.61	22.77	22.84	22.61	22.04	21.12	20.13	19.84	19.73

Table F15: R4-36 mains-side temperature values at 10LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.41	22.39	22.37	21.34	19.04	18.02	15.53	13.88	12.29	11.05	10.43	10.26
	0.07	22.41	22.39	22.37	21.41	19.27	18.32	16.01	14.47	12.97	11.73	11.12	10.96
	0.13	22.41	22.39	22.38	21.49	19.51	18.63	16.50	15.07	13.64	12.42	11.81	11.66
	0.20	22.41	22.39	22.38	21.56	19.74	18.93	16.98	15.66	14.32	13.10	12.50	12.36
	0.27	22.41	22.40	22.38	21.64	19.97	19.24	17.46	16.26	14.99	13.79	13.19	13.05
	0.33	22.41	22.40	22.38	21.71	20.20	19.54	17.94	16.85	15.67	14.47	13.88	13.75
	0.40	22.41	22.40	22.39	21.78	20.44	19.85	18.43	17.45	16.35	15.16	14.57	14.45
	0.47	22.41	22.40	22.39	21.86	20.67	20.15	18.91	18.04	17.02	15.84	15.26	15.15
	0.53	22.41	22.40	22.39	21.93	20.90	20.46	19.39	18.64	17.70	16.53	15.96	15.85
	0.60	22.41	22.40	22.39	22.01	21.13	20.76	19.87	19.23	18.37	17.21	16.65	16.55
	0.67	22.41	22.40	22.40	22.08	21.37	21.07	20.36	19.83	19.05	17.90	17.34	17.25
	0.73	22.41	22.40	22.40	22.15	21.60	21.37	20.84	20.42	19.73	18.58	18.03	17.95
	0.80	22.41	22.41	22.40	22.23	21.83	21.68	21.32	21.02	20.40	19.27	18.72	18.64
	0.87	22.41	22.41	22.40	22.30	22.06	21.98	21.80	21.61	21.08	19.95	19.41	19.34
	0.93	22.41	22.41	22.41	22.38	22.30	22.29	22.29	22.21	21.75	20.64	20.10	20.04
	1.00	22.41	22.41	22.41	22.45	22.53	22.59	22.77	22.80	22.43	21.32	20.79	20.74
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.19	22.21	21.95	21.13	19.50	18.48	16.16	14.49	12.63	11.23	10.49	10.31
	0.11	22.31	22.29	22.17	21.44	19.72	18.58	16.35	14.85	13.16	11.96	11.34	11.20
	0.22	22.31	22.30	22.23	21.57	20.02	19.00	17.40	16.37	15.08	14.00	13.53	13.45
	0.33	22.31	22.32	22.30	22.11	20.98	20.02	18.39	17.43	16.14	15.09	14.62	14.52
	0.44	22.34	22.35	22.36	22.34	21.71	20.94	19.46	18.56	17.27	16.26	15.71	15.63
	0.56	22.28	22.32	22.33	22.37	22.14	21.74	21.03	20.53	19.57	18.72	18.28	18.30
	0.67	22.26	22.29	22.32	22.37	22.38	22.32	22.18	21.99	21.20	20.43	20.02	20.08
	0.78	22.26	22.29	22.32	22.38	22.50	22.64	23.03	23.11	22.53	21.82	21.47	21.51
	0.89	22.28	22.31	22.34	22.41	22.54	22.70	23.28	23.67	23.39	22.74	22.46	22.45
	1.00	22.18	22.20	22.23	22.29	22.38	22.46	22.59	22.62	22.09	21.13	20.70	20.69
COILSET SURFACE TEMPERATURE (°C)	0.00	22.41	22.39	22.37	21.34	19.04	18.02	15.53	13.88	12.29	11.05	10.43	10.26
	0.07	21.71	21.68	21.63	21.15	19.55	18.47	16.39	15.22	13.85	12.71	11.93	11.97
	0.13	21.72	21.69	21.66	21.41	19.96	18.85	16.72	15.48	14.10	12.87	12.06	12.06
	0.20	21.70	21.67	21.66	21.56	20.42	19.44	17.41	16.30	14.95	13.76	13.03	13.07
	0.27	21.69	21.66	21.66	21.64	20.79	19.87	17.88	16.80	15.47	14.27	13.52	13.66
	0.33	21.67	21.64	21.63	21.64	21.08	20.26	18.41	17.41	16.17	14.95	14.24	14.37
	0.40	21.64	21.62	21.63	21.65	21.33	20.72	19.12	18.24	17.07	15.90	15.22	15.37
	0.47	21.63	21.61	21.64	21.66	21.53	21.07	19.70	18.96	17.87	16.72	16.04	16.17
	0.53	21.65	21.65	21.66	21.69	21.69	21.44	20.37	19.81	18.81	17.70	17.02	17.18
	0.60	21.61	21.61	21.64	21.69	21.76	21.65	20.85	20.45	19.55	18.48	17.84	17.90
	0.67	21.61	21.60	21.62	21.68	21.78	21.81	21.36	21.16	20.42	19.46	18.83	18.90
	0.73	21.58	21.58	21.61	21.66	21.80	21.93	21.85	21.84	21.28	20.40	19.86	19.87
	0.80	21.56	21.57	21.60	21.65	21.83	22.03	22.26	22.48	22.05	21.22	20.66	20.69
	0.87	21.56	21.56	21.58	21.65	21.83	22.08	22.58	22.89	22.56	21.75	21.22	21.25
	0.93	21.62	21.60	21.63	21.71	21.88	22.15	22.86	23.37	23.23	22.48	21.95	22.01
	1.00	22.41	22.41	22.41	22.45	22.53	22.59	22.77	22.80	22.43	21.32	20.79	20.74

Table F16: R4-36 mains-side temperature values at 9LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.33	22.12	21.30	20.52	18.67	17.74	15.20	13.94	12.18	11.03	10.35	10.16
	0.07	22.35	22.15	21.39	20.66	18.93	18.07	15.70	14.51	12.80	11.74	11.08	10.90
	0.13	22.36	22.18	21.47	20.80	19.20	18.39	16.21	15.09	13.42	12.45	11.81	11.64
	0.20	22.38	22.21	21.56	20.94	19.46	18.72	16.71	15.66	14.04	13.16	12.54	12.38
	0.27	22.40	22.25	21.65	21.08	19.72	19.05	17.22	16.24	14.66	13.87	13.26	13.13
	0.33	22.41	22.28	21.74	21.22	19.99	19.37	17.72	16.81	15.28	14.58	13.99	13.87
	0.40	22.43	22.31	21.82	21.36	20.25	19.70	18.23	17.39	15.90	15.29	14.72	14.61
	0.47	22.45	22.34	21.91	21.50	20.51	20.03	18.73	17.96	16.52	16.00	15.45	15.35
	0.53	22.46	22.37	22.00	21.64	20.78	20.35	19.24	18.54	17.14	16.72	16.18	16.09
	0.60	22.48	22.40	22.09	21.78	21.04	20.68	19.74	19.11	17.76	17.43	16.91	16.83
	0.67	22.50	22.43	22.17	21.92	21.30	21.01	20.25	19.69	18.38	18.14	17.64	17.57
	0.73	22.51	22.46	22.26	22.06	21.57	21.33	20.75	20.26	19.00	18.85	18.37	18.31
	0.80	22.53	22.50	22.35	22.20	21.83	21.66	21.26	20.84	19.62	19.56	19.09	19.06
	0.87	22.55	22.53	22.44	22.34	22.09	21.99	21.76	21.41	20.24	20.27	19.82	19.80
	0.93	22.56	22.56	22.52	22.48	22.36	22.31	22.27	21.99	20.86	20.98	20.55	20.54
	1.00	22.58	22.59	22.61	22.62	22.62	22.64	22.77	22.56	21.48	21.69	21.28	21.28
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.08	21.90	21.55	20.67	19.11	18.17	16.03	14.57	12.66	11.30	10.43	10.20
	0.11	22.25	22.11	21.81	20.90	19.27	18.25	16.10	14.53	12.80	12.01	11.31	11.13
	0.22	22.30	22.19	21.92	21.08	19.53	18.53	16.41	14.91	13.47	14.03	13.51	13.38
	0.33	22.29	22.30	22.25	21.84	20.56	19.61	17.50	15.91	14.32	15.20	14.67	14.55
	0.44	22.34	22.35	22.35	22.23	21.38	20.56	18.52	16.97	15.45	16.47	15.91	15.78
	0.56	22.37	22.37	22.37	22.36	21.93	21.35	19.73	18.43	17.73	18.99	18.57	18.49
	0.67	22.42	22.43	22.41	22.41	22.31	22.02	20.97	19.95	19.50	20.74	20.39	20.36
	0.78	22.50	22.50	22.49	22.50	22.54	22.53	22.12	21.54	21.29	22.22	21.95	21.97
	0.89	22.58	22.58	22.59	22.59	22.65	22.74	22.87	22.74	22.43	23.26	23.03	23.10
	1.00	22.38	22.42	22.41	22.43	22.46	22.53	22.55	22.21	21.21	21.58	21.19	21.19
COILSET SURFACE TEMPERATURE (°C)	0.00	22.33	22.12	21.30	20.52	18.67	17.74	15.20	13.94	12.18	11.03	10.35	10.16
	0.07	21.75	21.57	21.20	20.30	18.74	17.98	16.26	15.08	13.86	12.85	12.30	12.19
	0.13	21.78	21.73	21.47	20.65	19.08	18.25	16.43	15.20	13.88	12.93	12.37	12.27
	0.20	21.81	21.80	21.67	21.06	19.61	18.85	17.13	15.91	14.62	13.87	13.39	13.21
	0.27	21.77	21.78	21.74	21.31	20.02	19.29	17.56	16.35	15.03	14.46	14.01	13.83
	0.33	21.77	21.78	21.76	21.52	20.40	19.74	18.07	16.92	15.58	15.17	14.74	14.57
	0.40	21.80	21.82	21.81	21.72	20.85	20.27	18.79	17.68	16.40	16.15	15.75	15.60
	0.47	21.84	21.83	21.85	21.84	21.21	20.75	19.43	18.39	17.11	17.00	16.60	16.43
	0.53	21.84	21.84	21.85	21.87	21.50	21.20	20.10	19.18	17.96	17.99	17.59	17.50
	0.60	21.88	21.88	21.87	21.88	21.73	21.56	20.71	19.89	18.75	18.90	18.46	18.45
	0.67	21.90	21.90	21.88	21.90	21.90	21.85	21.23	20.53	19.49	19.74	19.31	19.35
	0.73	21.89	21.90	21.88	21.90	21.99	22.11	21.79	21.24	20.40	20.73	20.39	20.45
	0.80	21.96	21.98	21.96	21.98	22.14	22.36	22.30	21.89	21.12	21.48	21.16	21.23
	0.87	21.95	21.97	21.96	21.98	22.18	22.51	22.73	22.47	21.77	22.21	21.88	21.98
	0.93	21.97	22.00	22.00	22.03	22.20	22.60	23.10	23.01	22.44	22.91	22.65	22.76
	1.00	22.58	22.59	22.61	22.62	22.62	22.64	22.77	22.56	21.48	21.69	21.28	21.28

Table F17: R4-36 mains-side temperature values at 7LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.35	22.35	22.34	21.63	20.17	19.60	17.35	15.74	13.80	11.99	10.88	10.55
	0.07	22.35	22.35	22.34	21.68	20.32	19.79	17.71	16.23	14.41	12.60	11.57	11.34
	0.13	22.35	22.35	22.34	21.73	20.48	19.99	18.08	16.73	15.01	13.21	12.26	12.12
	0.20	22.35	22.35	22.35	21.79	20.63	20.18	18.44	17.22	15.62	13.82	12.95	12.91
	0.27	22.35	22.36	22.35	21.84	20.78	20.37	18.80	17.71	16.22	14.43	13.64	13.69
	0.33	22.35	22.36	22.35	21.89	20.94	20.57	19.16	18.21	16.83	15.04	14.33	14.48
	0.40	22.35	22.36	22.35	21.94	21.09	20.76	19.53	18.70	17.44	15.65	15.02	15.27
	0.47	22.35	22.36	22.35	21.99	21.24	20.95	19.89	19.19	18.04	16.26	15.71	16.05
	0.53	22.36	22.36	22.36	22.05	21.40	21.15	20.25	19.69	18.65	16.86	16.40	16.84
	0.60	22.36	22.36	22.36	22.10	21.55	21.34	20.61	20.18	19.25	17.47	17.09	17.62
	0.67	22.36	22.36	22.36	22.15	21.70	21.53	20.98	20.67	19.86	18.08	17.78	18.41
	0.73	22.36	22.36	22.36	22.20	21.86	21.73	21.34	21.17	20.47	18.69	18.47	19.20
	0.80	22.36	22.37	22.36	22.25	22.01	21.92	21.70	21.66	21.07	19.30	19.16	19.98
	0.87	22.36	22.37	22.37	22.31	22.16	22.11	22.06	22.15	21.68	19.91	19.85	20.77
	0.93	22.36	22.37	22.37	22.36	22.32	22.31	22.43	22.65	22.28	20.52	20.54	21.55
	1.00	22.36	22.37	22.37	22.41	22.47	22.50	22.79	23.14	22.89	21.13	21.23	22.34
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.27	22.24	22.16	21.80	20.92	20.23	18.46	16.87	14.53	12.35	10.98	10.61
	0.11	22.36	22.34	22.29	22.01	21.13	20.38	18.45	16.78	14.45	12.39	11.49	11.23
	0.22	22.38	22.37	22.35	22.12	21.31	20.61	18.75	17.11	14.76	12.67	12.91	12.72
	0.33	22.37	22.38	22.37	22.34	21.96	21.47	19.80	18.16	15.71	13.41	13.94	13.92
	0.44	22.36	22.38	22.40	22.39	22.30	22.03	20.74	19.21	16.78	14.35	15.21	15.32
	0.56	22.31	22.34	22.36	22.39	22.39	22.32	21.56	20.35	18.23	15.81	17.64	17.87
	0.67	22.29	22.30	22.32	22.36	22.40	22.43	22.21	21.48	19.80	17.57	19.67	20.06
	0.78	22.29	22.31	22.32	22.38	22.44	22.51	22.71	22.58	21.60	19.78	21.74	22.22
	0.89	22.33	22.34	22.35	22.40	22.47	22.55	22.95	23.30	23.16	21.71	23.30	24.00
	1.00	22.14	22.15	22.17	22.20	22.26	22.33	22.65	22.94	22.58	20.89	21.28	22.23
COILSET SURFACE TEMPERATURE (°C)	0.00	22.35	22.35	22.34	21.63	20.17	19.60	17.35	15.74	13.80	11.99	10.88	10.55
	0.07	21.57	21.57	21.41	21.11	20.22	19.54	17.96	16.84	15.12	13.78	12.84	12.75
	0.13	21.58	21.58	21.48	21.32	20.57	19.89	18.24	17.07	15.21	13.71	12.96	12.85
	0.20	21.60	21.59	21.50	21.47	20.91	20.35	18.82	17.68	15.85	14.39	13.89	13.85
	0.27	21.56	21.56	21.48	21.52	21.17	20.72	19.32	18.18	16.35	14.94	14.61	14.60
	0.33	21.55	21.56	21.48	21.55	21.36	21.02	19.77	18.66	16.85	15.43	15.27	15.35
	0.40	21.54	21.56	21.49	21.57	21.50	21.32	20.35	19.38	17.69	16.31	16.33	16.42
	0.47	21.51	21.54	21.48	21.55	21.58	21.53	20.82	19.99	18.41	17.03	17.19	17.33
	0.53	21.48	21.53	21.45	21.54	21.62	21.69	21.28	20.65	19.19	17.88	18.20	18.46
	0.60	21.46	21.50	21.44	21.54	21.65	21.80	21.65	21.19	19.87	18.51	18.89	19.18
	0.67	21.42	21.45	21.39	21.51	21.63	21.80	21.94	21.72	20.63	19.38	19.86	20.29
	0.73	21.42	21.45	21.37	21.47	21.62	21.85	22.23	22.25	21.45	20.28	20.85	21.32
	0.80	21.43	21.46	21.39	21.50	21.67	21.93	22.51	22.75	22.14	20.96	21.60	22.16
	0.87	21.42	21.46	21.40	21.50	21.69	21.94	22.70	23.19	22.82	21.65	22.33	22.94
	0.93	21.45	21.48	21.43	21.53	21.71	21.96	22.79	23.52	23.47	22.33	23.02	23.75
	1.00	22.36	22.37	22.37	22.41	22.47	22.50	22.79	23.14	22.89	21.13	21.23	22.34

Table F18: R4-36 mains-side temperature values at 5.5LPM for selected time instants

	Dist	1 sec	2 sec	3 sec	5 sec	8 sec	10 sec	15 sec	20 sec	30 sec	50 sec	100 sec	200 sec
ESTIMATED WATER TEMPERATURE (°C)	0.00	22.05	21.83	21.60	21.07	20.18	19.22	17.56	16.35	14.17	12.08	10.71	10.21
	0.07	22.08	21.87	21.66	21.16	20.34	19.44	17.91	16.81	14.78	12.71	11.34	10.87
	0.13	22.10	21.91	21.72	21.26	20.49	19.67	18.26	17.26	15.40	13.34	11.96	11.54
	0.20	22.13	21.96	21.77	21.35	20.65	19.89	18.62	17.72	16.01	13.97	12.59	12.20
	0.27	22.16	22.00	21.83	21.45	20.80	20.12	18.97	18.17	16.62	14.59	13.22	12.87
	0.33	22.19	22.04	21.89	21.54	20.96	20.34	19.32	18.63	17.23	15.22	13.84	13.53
	0.40	22.21	22.08	21.95	21.64	21.12	20.56	19.67	19.09	17.85	15.85	14.47	14.20
	0.47	22.24	22.12	22.01	21.73	21.27	20.79	20.02	19.54	18.46	16.48	15.10	14.86
	0.53	22.27	22.17	22.06	21.83	21.43	21.01	20.38	20.00	19.07	17.11	15.72	15.53
	0.60	22.30	22.21	22.12	21.92	21.58	21.24	20.73	20.45	19.68	17.74	16.35	16.19
	0.67	22.32	22.25	22.18	22.02	21.74	21.46	21.08	20.91	20.30	18.37	16.98	16.86
	0.73	22.35	22.29	22.24	22.11	21.90	21.68	21.43	21.37	20.91	19.00	17.60	17.52
	0.80	22.38	22.33	22.30	22.21	22.05	21.91	21.78	21.82	21.52	19.62	18.23	18.19
	0.87	22.41	22.38	22.35	22.30	22.21	22.13	22.14	22.28	22.13	20.25	18.86	18.85
	0.93	22.43	22.42	22.41	22.40	22.36	22.36	22.49	22.73	22.75	20.88	19.48	19.52
	1.00	22.46	22.46	22.47	22.49	22.52	22.58	22.84	23.19	23.36	21.51	20.11	20.18
THERMOCOUPLE SURFACE TEMPERATURE (°C)	0.00	22.24	22.09	21.94	21.51	20.74	20.18	18.74	17.42	15.23	12.75	11.03	10.45
	0.11	22.33	22.25	22.12	21.72	20.91	20.33	18.74	17.36	15.17	12.78	11.17	10.64
	0.22	22.38	22.30	22.20	21.87	21.14	20.58	19.08	17.70	15.44	13.08	11.47	10.98
	0.33	22.42	22.40	22.39	22.27	21.86	21.45	20.13	18.77	16.46	13.83	12.19	11.71
	0.44	22.42	22.42	22.43	22.41	22.26	22.05	21.08	19.88	17.59	14.81	13.06	12.62
	0.56	22.35	22.35	22.37	22.38	22.36	22.30	21.77	20.90	18.87	16.15	14.42	14.10
	0.67	22.32	22.33	22.35	22.36	22.40	22.42	22.30	21.85	20.29	17.76	16.05	15.94
	0.78	22.29	22.31	22.33	22.35	22.41	22.48	22.65	22.63	21.66	19.61	18.32	18.65
	0.89	22.30	22.31	22.32	22.34	22.41	22.49	22.80	23.11	22.93	21.40	20.84	21.65
	1.00	22.40	22.41	22.42	22.43	22.49	22.57	22.87	23.26	23.24	21.48	20.19	20.26
COILSET SURFACE TEMPERATURE (°C)	0.00	22.05	21.83	21.60	21.07	20.18	19.22	17.56	16.35	14.17	12.08	10.71	10.21
	0.07	21.52	21.48	21.33	20.88	20.09	19.46	18.28	17.22	15.62	13.71	12.95	12.60
	0.13	21.59	21.58	21.49	21.14	20.43	19.83	18.65	17.52	15.82	13.72	12.89	12.49
	0.20	21.61	21.63	21.60	21.36	20.84	20.31	19.29	18.25	16.58	14.45	13.64	13.27
	0.27	21.63	21.67	21.66	21.54	21.18	20.74	19.90	18.95	17.31	15.04	14.21	13.80
	0.33	21.63	21.66	21.66	21.60	21.39	21.05	20.38	19.53	17.92	15.61	14.75	14.38
	0.40	21.63	21.69	21.69	21.67	21.59	21.38	21.00	20.32	18.86	16.58	15.74	15.43
	0.47	21.63	21.68	21.69	21.69	21.73	21.62	21.52	21.03	19.71	17.41	16.56	16.32
	0.53	21.62	21.68	21.70	21.70	21.81	21.81	21.96	21.62	20.47	18.20	17.34	17.22
	0.60	21.63	21.70	21.70	21.72	21.86	21.89	22.30	22.18	21.21	18.99	18.10	18.06
	0.67	21.57	21.62	21.65	21.68	21.85	21.92	22.50	22.55	21.81	19.75	18.92	18.90
	0.73	21.55	21.61	21.62	21.65	21.83	21.95	22.71	23.00	22.53	20.72	19.90	20.06
	0.80	21.53	21.59	21.63	21.66	21.88	22.01	22.93	23.42	23.17	21.38	20.63	20.82
	0.87	21.60	21.65	21.68	21.71	21.93	22.10	23.12	23.80	23.82	22.10	21.35	21.59
	0.93	21.61	21.66	21.69	21.71	21.93	22.10	23.18	24.03	24.37	22.84	22.22	22.49
	1.00	22.46	22.46	22.47	22.49	22.52	22.58	22.84	23.19	23.36	21.51	20.11	20.18

Appendix G: MATLAB Script for Centre-Line Temperature Estimation

```
% load file for 1st frame
M = csvread ('Rec-000018_1371.csv');
for n = 25:40      % Set 1
    value1 = M(70,n);
    counter1 = counter1 + 1;
    Tcoilset1 = Tcoilset1 + value1;
end
for n = 45:60      % Set 2
    value1 = M(70,n);
    counter2 = counter2 + 1;
    Tcoilset2 = Tcoilset2 + value1;
end
for n = 65:81      % Set 3
    value1 = M(70,n);
    counter3 = counter3 + 1;
    Tcoilset3 = Tcoilset3 + value1;
end

% Do this till coil set 14 or 24 depending on pipe

% load file for 2nd frame
M = csvread ('Rec-000018_1372.csv');
% Run All For Loops as Above

% load file for 3rd frame
M = csvread ('Rec-000018_1373.csv');
% Run All For Loops as Above

% load file for 4th frame
M = csvread ('Rec-000018_1374.csv');
% Run All For Loops as Above

% load file for 5th frame
M = csvread ('Rec-000018_1375.csv');
% Run All For Loops as Above

% load file for 6th frame
M = csvread ('Rec-000018_1376.csv');
% Run All For Loops as Above

% load file for 7th frame
M = csvread ('Rec-000018_1377.csv');
% Run All For Loops as Above

% load files for all frames in the specific time instant.
% usually each time instant had 6 or 7 frames.

Tcoilset1 = Tcoilset1/counter1;
Tcoilset2 = Tcoilset2/counter2;
Tcoilset3 = Tcoilset3/counter3;
Tcoilset4 = Tcoilset4/counter4;
Tcoilset5 = Tcoilset5/counter5;
Tcoilset6 = Tcoilset6/counter6;
Tcoilset7 = Tcoilset7/counter7;
Tcoilset8 = Tcoilset8/counter8;
Tcoilset9 = Tcoilset9/counter9;
Tcoilset10 = Tcoilset10/counter10;
Tcoilset11 = Tcoilset11/counter11;
Tcoilset12 = Tcoilset12/counter12;
Tcoilset13 = Tcoilset13/counter13;
Tcoilset14 = Tcoilset14/counter14;
```


Appendix H: Biot Number and Convection Coefficient Tables at Coil Sets

Table H1: Heat transfer coefficients and Biot number approximations for R3-36 at 14LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4355	0.0162	6072	0.0226	4929	0.0183	7476	0.0278	5286	0.0197	8409	0.0313	5234	0.0195	8310	0.0309
2	4355	0.0162	6073	0.0226	4929	0.0184	7477	0.0278	5286	0.0197	8410	0.0313	5239	0.0195	8320	0.0310
3	4356	0.0162	6073	0.0226	4929	0.0184	7477	0.0278	5287	0.0197	8412	0.0313	5244	0.0195	8331	0.0310
4	4356	0.0162	6074	0.0226	4930	0.0184	7479	0.0278	5287	0.0197	8413	0.0313	5249	0.0195	8341	0.0311
5	4356	0.0162	6075	0.0226	4930	0.0184	7480	0.0278	5288	0.0197	8413	0.0313	5254	0.0196	8351	0.0311
6	4357	0.0162	6076	0.0226	4931	0.0184	7480	0.0279	5288	0.0197	8414	0.0313	5259	0.0196	8362	0.0311
7	4358	0.0162	6076	0.0226	4931	0.0184	7481	0.0279	5289	0.0197	8415	0.0313	5265	0.0196	8372	0.0312
8	4358	0.0162	6077	0.0226	4932	0.0184	7482	0.0279	5289	0.0197	8417	0.0313	5269	0.0196	8381	0.0312
9	4358	0.0162	6078	0.0226	4932	0.0184	7483	0.0279	5290	0.0197	8418	0.0313	5274	0.0196	8391	0.0312
10	4359	0.0162	6079	0.0226	4932	0.0184	7483	0.0279	5290	0.0197	8418	0.0313	5278	0.0197	8400	0.0313
11	4359	0.0162	6079	0.0226	4933	0.0184	7484	0.0279	5291	0.0197	8419	0.0313	5283	0.0197	8409	0.0313
12	4360	0.0162	6080	0.0226	4934	0.0184	7486	0.0279	5291	0.0197	8420	0.0313	5287	0.0197	8418	0.0313
13	4360	0.0162	6081	0.0226	4934	0.0184	7486	0.0279	5292	0.0197	8422	0.0314	5292	0.0197	8428	0.0314
14	4361	0.0162	6082	0.0226	4934	0.0184	7487	0.0279	5292	0.0197	8423	0.0314	5296	0.0197	8437	0.0314
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	5092	0.0190	8020	0.0299	5048	0.0188	7939	0.0296	4918	0.0183	7673	0.0286	4928	0.0183	7740	0.0288
2	5106	0.0190	8049	0.0300	5065	0.0189	7971	0.0297	4940	0.0184	7715	0.0287	4952	0.0184	7787	0.0290
3	5120	0.0191	8076	0.0301	5081	0.0189	8004	0.0298	4962	0.0185	7758	0.0289	4977	0.0185	7836	0.0292
4	5134	0.0191	8104	0.0302	5098	0.0190	8038	0.0299	4984	0.0186	7800	0.0290	5002	0.0186	7884	0.0294
5	5148	0.0192	8133	0.0303	5115	0.0190	8072	0.0301	5007	0.0186	7844	0.0292	5027	0.0187	7934	0.0295
6	5163	0.0192	8162	0.0304	5132	0.0191	8106	0.0302	5030	0.0187	7888	0.0294	5053	0.0188	7984	0.0297
7	5177	0.0193	8191	0.0305	5149	0.0192	8140	0.0303	5051	0.0188	7931	0.0295	5079	0.0189	8035	0.0299
8	5191	0.0193	8219	0.0306	5166	0.0192	8175	0.0304	5073	0.0189	7974	0.0297	5105	0.0190	8086	0.0301
9	5206	0.0194	8249	0.0307	5184	0.0193	8210	0.0306	5095	0.0190	8019	0.0299	5131	0.0191	8137	0.0303
10	5221	0.0194	8279	0.0308	5201	0.0194	8245	0.0307	5118	0.0191	8064	0.0300	5156	0.0192	8189	0.0305
11	5236	0.0195	8309	0.0309	5219	0.0194	8281	0.0308	5141	0.0191	8109	0.0302	5182	0.0193	8241	0.0307
12	5250	0.0195	8339	0.0310	5237	0.0195	8318	0.0310	5164	0.0192	8156	0.0304	5209	0.0194	8294	0.0309
13	5265	0.0196	8368	0.0312	5255	0.0196	8354	0.0311	5187	0.0193	8202	0.0305	5235	0.0195	8349	0.0311
14	5278	0.0197	8395	0.0313	5273	0.0196	8390	0.0312	5211	0.0194	8250	0.0307	5262	0.0196	8403	0.0313
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4877	0.0182	7646	0.0285	4810	0.0179	7492	0.0279	4790	0.0178	7453	0.0277	4780	0.0178	7428	0.0277
2	4908	0.0183	7711	0.0287	4844	0.0180	7563	0.0282	4825	0.0180	7524	0.0280	4813	0.0179	7497	0.0279
3	4933	0.0184	7760	0.0289	4878	0.0182	7634	0.0284	4859	0.0181	7595	0.0283	4848	0.0180	7570	0.0282
4	4959	0.0185	7808	0.0291	4902	0.0183	7682	0.0286	4889	0.0182	7656	0.0285	4880	0.0182	7636	0.0284
5	4984	0.0186	7859	0.0293	4928	0.0183	7732	0.0288	4915	0.0183	7707	0.0287	4906	0.0183	7685	0.0286
6	5011	0.0187	7910	0.0294	4954	0.0184	7782	0.0290	4941	0.0184	7757	0.0289	4932	0.0184	7736	0.0288
7	5037	0.0188	7960	0.0296	4980	0.0185	7832	0.0292	4967	0.0185	7808	0.0291	4958	0.0185	7787	0.0290
8	5063	0.0189	8013	0.0298	5007	0.0186	7884	0.0294	4994	0.0186	7860	0.0293	4985	0.0186	7838	0.0292
9	5090	0.0190	8065	0.0300	5033	0.0187	7936	0.0295	5021	0.0187	7912	0.0295	5012	0.0187	7891	0.0294
10	5118	0.0191	8119	0.0302	5060	0.0188	7988	0.0297	5048	0.0188	7965	0.0297	5040	0.0188	7945	0.0296
11	5144	0.0192	8172	0.0304	5088	0.0189	8043	0.0299	5077	0.0189	8020	0.0299	5067	0.0189	7999	0.0298
12	5171	0.0192	8225	0.0306	5114	0.0190	8095	0.0301	5104	0.0190	8074	0.0301	5095	0.0190	8053	0.0300
13	5198	0.0194	8280	0.0308	5141	0.0191	8149	0.0303	5131	0.0191	8128	0.0303	5122	0.0191	8108	0.0302
14	5225	0.0195	8335	0.0310	5168	0.0192	8204	0.0305	5158	0.0192	8184	0.0305	5150	0.0192	8163	0.0304

Table H2: Heat transfer coefficients and Biot number approximations for R3-36 at 12LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4458	0.0166	6316	0.0235	4878	0.0182	7348	0.0274	4903	0.0183	7411	0.0276	4857	0.0181	7327	0.0273
2	4458	0.0166	6317	0.0235	4878	0.0182	7349	0.0274	4903	0.0183	7413	0.0276	4862	0.0181	7336	0.0273
3	4459	0.0166	6318	0.0235	4879	0.0182	7350	0.0274	4904	0.0183	7413	0.0276	4866	0.0181	7344	0.0273
4	4460	0.0166	6319	0.0235	4879	0.0182	7351	0.0274	4904	0.0183	7415	0.0276	4870	0.0181	7353	0.0274
5	4460	0.0166	6320	0.0235	4880	0.0182	7352	0.0274	4905	0.0183	7416	0.0276	4875	0.0182	7362	0.0274
6	4460	0.0166	6320	0.0235	4880	0.0182	7352	0.0274	4905	0.0183	7416	0.0276	4879	0.0182	7370	0.0274
7	4461	0.0166	6321	0.0235	4881	0.0182	7353	0.0274	4906	0.0183	7418	0.0276	4884	0.0182	7378	0.0275
8	4461	0.0166	6322	0.0235	4881	0.0182	7355	0.0274	4906	0.0183	7419	0.0276	4888	0.0182	7387	0.0275
9	4462	0.0166	6323	0.0235	4882	0.0182	7355	0.0274	4907	0.0183	7420	0.0276	4892	0.0182	7394	0.0275
10	4462	0.0166	6323	0.0235	4882	0.0182	7356	0.0274	4908	0.0183	7421	0.0276	4896	0.0182	7402	0.0276
11	4462	0.0166	6324	0.0235	4882	0.0182	7357	0.0274	4908	0.0183	7422	0.0276	4900	0.0182	7410	0.0276
12	4463	0.0166	6325	0.0235	4883	0.0182	7358	0.0274	4909	0.0183	7423	0.0276	4904	0.0183	7417	0.0276
13	4463	0.0166	6326	0.0236	4884	0.0182	7359	0.0274	4909	0.0183	7424	0.0276	4908	0.0183	7425	0.0276
14	4464	0.0166	6327	0.0236	4884	0.0182	7360	0.0274	4910	0.0183	7425	0.0276	4912	0.0183	7433	0.0277
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4814	0.0179	7252	0.0270	4745	0.0177	7121	0.0265	4641	0.0173	6936	0.0258	4598	0.0171	6861	0.0255
2	4822	0.0180	7268	0.0271	4757	0.0177	7146	0.0266	4661	0.0174	6973	0.0260	4620	0.0172	6902	0.0257
3	4831	0.0180	7284	0.0271	4771	0.0178	7171	0.0267	4681	0.0174	7009	0.0261	4643	0.0173	6944	0.0259
4	4839	0.0180	7300	0.0272	4784	0.0178	7196	0.0268	4701	0.0175	7047	0.0262	4666	0.0174	6987	0.0260
5	4848	0.0180	7316	0.0272	4797	0.0179	7221	0.0269	4721	0.0176	7084	0.0264	4690	0.0175	7030	0.0262
6	4856	0.0181	7331	0.0273	4810	0.0179	7246	0.0270	4740	0.0176	7121	0.0265	4713	0.0175	7073	0.0263
7	4864	0.0181	7348	0.0274	4823	0.0180	7272	0.0271	4760	0.0177	7159	0.0267	4736	0.0176	7117	0.0265
8	4873	0.0181	7364	0.0274	4837	0.0180	7298	0.0272	4780	0.0178	7197	0.0268	4759	0.0177	7160	0.0267
9	4881	0.0182	7381	0.0275	4851	0.0181	7324	0.0273	4800	0.0179	7235	0.0269	4782	0.0178	7205	0.0268
10	4889	0.0182	7397	0.0275	4864	0.0181	7350	0.0274	4821	0.0179	7275	0.0271	4806	0.0179	7250	0.0270
11	4898	0.0182	7413	0.0276	4878	0.0182	7377	0.0275	4841	0.0180	7314	0.0272	4829	0.0180	7295	0.0272
12	4906	0.0183	7428	0.0277	4892	0.0182	7403	0.0276	4862	0.0181	7355	0.0274	4853	0.0181	7342	0.0273
13	4913	0.0183	7443	0.0277	4905	0.0183	7430	0.0277	4883	0.0182	7395	0.0275	4878	0.0182	7389	0.0275
14	4921	0.0183	7457	0.0278	4918	0.0183	7454	0.0278	4904	0.0183	7436	0.0277	4903	0.0183	7436	0.0277
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4542	0.0169	6757	0.0252	4501	0.0168	6683	0.0249	4489	0.0167	6663	0.0248	4482	0.0167	6650	0.0248
2	4566	0.0170	6801	0.0253	4532	0.0169	6743	0.0251	4522	0.0168	6730	0.0251	4515	0.0168	6717	0.0250
3	4590	0.0171	6846	0.0255	4556	0.0170	6787	0.0253	4550	0.0169	6783	0.0253	4546	0.0169	6775	0.0252
4	4615	0.0172	6892	0.0257	4581	0.0171	6832	0.0254	4575	0.0170	6829	0.0254	4571	0.0170	6822	0.0254
5	4640	0.0173	6938	0.0258	4606	0.0171	6878	0.0256	4600	0.0171	6875	0.0256	4596	0.0171	6868	0.0256
6	4665	0.0174	6985	0.0260	4631	0.0172	6925	0.0258	4626	0.0172	6922	0.0258	4622	0.0172	6915	0.0257
7	4691	0.0175	7033	0.0262	4657	0.0173	6973	0.0260	4651	0.0173	6970	0.0259	4648	0.0173	6963	0.0259
8	4717	0.0176	7080	0.0264	4683	0.0174	7020	0.0261	4677	0.0174	7018	0.0261	4674	0.0174	7012	0.0261
9	4742	0.0177	7128	0.0265	4709	0.0175	7069	0.0263	4704	0.0175	7067	0.0263	4701	0.0175	7061	0.0263
10	4768	0.0177	7177	0.0267	4735	0.0176	7118	0.0265	4731	0.0176	7117	0.0265	4728	0.0176	7111	0.0265
11	4793	0.0178	7226	0.0269	4761	0.0177	7167	0.0267	4757	0.0177	7166	0.0267	4754	0.0177	7161	0.0267
12	4819	0.0179	7276	0.0271	4787	0.0178	7217	0.0269	4783	0.0178	7217	0.0269	4781	0.0178	7212	0.0269
13	4846	0.0180	7327	0.0273	4813	0.0179	7268	0.0271	4809	0.0179	7267	0.0271	4807	0.0179	7263	0.0270
14	4873	0.0181	7378	0.0275	4840	0.0180	7319	0.0272	4836	0.0180	7320	0.0273	4834	0.0180	7316	0.0272

Table H3: Heat transfer coefficients and Biot number approximations for R3-36 at 10LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4499	0.0168	6415	0.0239	4501	0.0168	6421	0.0239	4503	0.0168	6427	0.0239	4472	0.0167	6369	0.0237
2	4500	0.0168	6417	0.0239	4503	0.0168	6424	0.0239	4505	0.0168	6429	0.0239	4476	0.0167	6377	0.0237
3	4501	0.0168	6419	0.0239	4504	0.0168	6426	0.0239	4506	0.0168	6432	0.0239	4480	0.0167	6383	0.0238
4	4503	0.0168	6421	0.0239	4505	0.0168	6428	0.0239	4507	0.0168	6435	0.0240	4483	0.0167	6390	0.0238
5	4504	0.0168	6423	0.0239	4506	0.0168	6430	0.0239	4509	0.0168	6437	0.0240	4487	0.0167	6396	0.0238
6	4505	0.0168	6425	0.0239	4507	0.0168	6432	0.0239	4510	0.0168	6440	0.0240	4490	0.0167	6402	0.0238
7	4506	0.0168	6427	0.0239	4509	0.0168	6435	0.0240	4512	0.0168	6442	0.0240	4493	0.0167	6408	0.0239
8	4506	0.0168	6428	0.0239	4510	0.0168	6436	0.0240	4513	0.0168	6444	0.0240	4497	0.0167	6414	0.0239
9	4507	0.0168	6430	0.0239	4511	0.0168	6439	0.0240	4514	0.0168	6447	0.0240	4500	0.0168	6420	0.0239
10	4509	0.0168	6432	0.0239	4512	0.0168	6441	0.0240	4515	0.0168	6450	0.0240	4503	0.0168	6426	0.0239
11	4510	0.0168	6434	0.0240	4513	0.0168	6443	0.0240	4517	0.0168	6452	0.0240	4507	0.0168	6432	0.0239
12	4511	0.0168	6436	0.0240	4515	0.0168	6446	0.0240	4518	0.0168	6455	0.0240	4510	0.0168	6438	0.0240
13	4512	0.0168	6438	0.0240	4516	0.0168	6448	0.0240	4520	0.0168	6457	0.0240	4513	0.0168	6444	0.0240
14	4513	0.0168	6440	0.0240	4517	0.0168	6450	0.0240	4521	0.0168	6460	0.0241	4516	0.0168	6450	0.0240
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4410	0.0164	6271	0.0233	4353	0.0162	6167	0.0230	4267	0.0159	6011	0.0224	4220	0.0157	5934	0.0221
2	4419	0.0165	6287	0.0234	4366	0.0163	6189	0.0230	4285	0.0160	6043	0.0225	4241	0.0158	5971	0.0222
3	4429	0.0165	6305	0.0235	4379	0.0163	6213	0.0231	4303	0.0160	6074	0.0226	4262	0.0159	6008	0.0224
4	4438	0.0165	6322	0.0235	4391	0.0163	6235	0.0232	4321	0.0161	6106	0.0227	4284	0.0159	6046	0.0225
5	4448	0.0166	6339	0.0236	4404	0.0164	6259	0.0233	4338	0.0162	6137	0.0228	4306	0.0160	6084	0.0227
6	4457	0.0166	6356	0.0237	4418	0.0164	6283	0.0234	4356	0.0162	6169	0.0230	4328	0.0161	6122	0.0228
7	4467	0.0166	6374	0.0237	4431	0.0165	6306	0.0235	4374	0.0163	6202	0.0231	4349	0.0162	6161	0.0229
8	4477	0.0167	6392	0.0238	4444	0.0165	6331	0.0236	4392	0.0164	6234	0.0232	4371	0.0163	6200	0.0231
9	4487	0.0167	6410	0.0239	4457	0.0166	6355	0.0237	4410	0.0164	6267	0.0233	4393	0.0164	6239	0.0232
10	4496	0.0167	6427	0.0239	4471	0.0166	6379	0.0238	4429	0.0165	6301	0.0235	4415	0.0164	6279	0.0234
11	4506	0.0168	6445	0.0240	4485	0.0167	6404	0.0238	4448	0.0166	6335	0.0236	4437	0.0165	6320	0.0235
12	4515	0.0168	6461	0.0241	4498	0.0167	6429	0.0239	4467	0.0166	6370	0.0237	4460	0.0166	6361	0.0237
13	4524	0.0168	6478	0.0241	4511	0.0168	6453	0.0240	4486	0.0167	6404	0.0238	4483	0.0167	6403	0.0238
14	4533	0.0169	6493	0.0242	4523	0.0168	6475	0.0241	4505	0.0168	6439	0.0240	4507	0.0168	6446	0.0240
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4176	0.0155	5863	0.0218	4122	0.0153	5763	0.0215	4099	0.0153	5722	0.0213	4097	0.0153	5721	0.0213
2	4199	0.0156	5903	0.0220	4151	0.0155	5815	0.0216	4132	0.0154	5784	0.0215	4130	0.0154	5783	0.0215
3	4223	0.0157	5945	0.0221	4175	0.0155	5856	0.0218	4160	0.0155	5835	0.0217	4160	0.0155	5839	0.0217
4	4247	0.0158	5987	0.0223	4199	0.0156	5898	0.0220	4185	0.0156	5877	0.0219	4185	0.0156	5882	0.0219
5	4272	0.0159	6030	0.0224	4224	0.0157	5941	0.0221	4210	0.0157	5921	0.0220	4211	0.0157	5926	0.0221
6	4297	0.0160	6074	0.0226	4249	0.0158	5985	0.0223	4235	0.0158	5964	0.0222	4236	0.0158	5970	0.0222
7	4322	0.0161	6117	0.0228	4275	0.0159	6030	0.0224	4261	0.0159	6009	0.0224	4262	0.0159	6015	0.0224
8	4347	0.0162	6161	0.0229	4300	0.0160	6074	0.0226	4287	0.0160	6055	0.0225	4288	0.0160	6061	0.0226
9	4371	0.0163	6205	0.0231	4326	0.0161	6120	0.0228	4314	0.0161	6101	0.0227	4315	0.0161	6107	0.0227
10	4397	0.0164	6251	0.0233	4352	0.0162	6165	0.0230	4340	0.0162	6147	0.0229	4342	0.0162	6154	0.0229
11	4422	0.0165	6297	0.0234	4377	0.0163	6212	0.0231	4366	0.0163	6194	0.0231	4368	0.0163	6201	0.0231
12	4448	0.0166	6344	0.0236	4404	0.0164	6259	0.0233	4392	0.0164	6241	0.0232	4394	0.0164	6249	0.0233
13	4474	0.0167	6391	0.0238	4430	0.0165	6306	0.0235	4419	0.0165	6290	0.0234	4421	0.0165	6298	0.0234
14	4500	0.0168	6439	0.0240	4457	0.0166	6355	0.0237	4446	0.0166	6339	0.0236	4449	0.0166	6348	0.0236

Table H4: Heat transfer coefficients and Biot number approximations for R3-36 at 9LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4248	0.0158	5838	0.0217	4242	0.0158	5833	0.0217	4240	0.0158	5833	0.0217	4208	0.0157	5785	0.0215
2	4251	0.0158	5843	0.0218	4245	0.0158	5838	0.0217	4244	0.0158	5840	0.0217	4215	0.0157	5798	0.0216
3	4253	0.0158	5847	0.0218	4249	0.0158	5845	0.0218	4248	0.0158	5848	0.0218	4223	0.0157	5810	0.0216
4	4255	0.0158	5851	0.0218	4253	0.0158	5852	0.0218	4253	0.0158	5856	0.0218	4230	0.0157	5823	0.0217
5	4258	0.0159	5855	0.0218	4257	0.0158	5858	0.0218	4257	0.0158	5863	0.0218	4237	0.0158	5836	0.0217
6	4260	0.0159	5859	0.0218	4260	0.0159	5864	0.0218	4261	0.0159	5870	0.0219	4245	0.0158	5849	0.0218
7	4262	0.0159	5863	0.0218	4263	0.0159	5870	0.0219	4266	0.0159	5878	0.0219	4252	0.0158	5862	0.0218
8	4264	0.0159	5867	0.0218	4267	0.0159	5876	0.0219	4270	0.0159	5885	0.0219	4260	0.0159	5876	0.0219
9	4267	0.0159	5871	0.0219	4270	0.0159	5882	0.0219	4274	0.0159	5892	0.0219	4268	0.0159	5889	0.0219
10	4269	0.0159	5875	0.0219	4273	0.0159	5887	0.0219	4277	0.0159	5899	0.0220	4275	0.0159	5902	0.0220
11	4271	0.0159	5879	0.0219	4276	0.0159	5893	0.0219	4281	0.0159	5905	0.0220	4283	0.0159	5916	0.0220
12	4274	0.0159	5883	0.0219	4280	0.0159	5899	0.0220	4285	0.0160	5912	0.0220	4289	0.0160	5927	0.0221
13	4276	0.0159	5887	0.0219	4283	0.0159	5905	0.0220	4289	0.0160	5919	0.0220	4296	0.0160	5939	0.0221
14	4278	0.0159	5891	0.0219	4286	0.0160	5911	0.0220	4293	0.0160	5926	0.0221	4303	0.0160	5951	0.0222
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4175	0.0155	5738	0.0214	4137	0.0154	5672	0.0211	4071	0.0152	5561	0.0207	4018	0.0150	5466	0.0204
2	4186	0.0156	5756	0.0214	4150	0.0154	5695	0.0212	4089	0.0152	5591	0.0208	4039	0.0150	5501	0.0205
3	4197	0.0156	5775	0.0215	4163	0.0155	5718	0.0213	4107	0.0153	5621	0.0209	4060	0.0151	5536	0.0206
4	4207	0.0157	5793	0.0216	4176	0.0155	5742	0.0214	4125	0.0154	5652	0.0210	4081	0.0152	5572	0.0207
5	4218	0.0157	5812	0.0216	4190	0.0156	5765	0.0215	4142	0.0154	5682	0.0212	4103	0.0153	5608	0.0209
6	4229	0.0157	5831	0.0217	4203	0.0156	5789	0.0216	4159	0.0155	5712	0.0213	4124	0.0154	5644	0.0210
7	4240	0.0158	5850	0.0218	4217	0.0157	5813	0.0216	4177	0.0156	5743	0.0214	4145	0.0154	5681	0.0212
8	4251	0.0158	5870	0.0219	4231	0.0158	5837	0.0217	4195	0.0156	5774	0.0215	4166	0.0155	5717	0.0213
9	4262	0.0159	5889	0.0219	4245	0.0158	5861	0.0218	4213	0.0157	5806	0.0216	4188	0.0156	5755	0.0214
10	4273	0.0159	5909	0.0220	4259	0.0159	5886	0.0219	4231	0.0158	5838	0.0217	4209	0.0157	5793	0.0216
11	4285	0.0160	5929	0.0221	4273	0.0159	5911	0.0220	4250	0.0158	5871	0.0219	4231	0.0158	5832	0.0217
12	4296	0.0160	5949	0.0221	4287	0.0160	5936	0.0221	4268	0.0159	5903	0.0220	4254	0.0158	5871	0.0219
13	4306	0.0160	5967	0.0222	4302	0.0160	5962	0.0222	4287	0.0160	5936	0.0221	4277	0.0159	5911	0.0220
14	4316	0.0161	5985	0.0223	4315	0.0161	5985	0.0223	4306	0.0160	5970	0.0222	4299	0.0160	5950	0.0222
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3975	0.0148	5397	0.0201	3954	0.0147	5370	0.0200	3924	0.0146	5315	0.0198	3910	0.0146	5286	0.0197
2	3998	0.0149	5435	0.0202	3980	0.0148	5415	0.0202	3957	0.0147	5374	0.0200	3943	0.0147	5345	0.0199
3	4022	0.0150	5475	0.0204	4004	0.0149	5456	0.0203	3982	0.0148	5417	0.0202	3971	0.0148	5394	0.0201
4	4046	0.0151	5515	0.0205	4029	0.0150	5496	0.0205	4007	0.0149	5459	0.0203	3995	0.0149	5435	0.0202
5	4070	0.0152	5556	0.0207	4053	0.0151	5538	0.0206	4032	0.0150	5500	0.0205	4021	0.0150	5478	0.0204
6	4094	0.0152	5597	0.0208	4078	0.0152	5580	0.0208	4057	0.0151	5543	0.0206	4046	0.0151	5520	0.0206
7	4119	0.0153	5639	0.0210	4104	0.0153	5623	0.0209	4083	0.0152	5586	0.0208	4072	0.0152	5564	0.0207
8	4143	0.0154	5681	0.0211	4130	0.0154	5667	0.0211	4108	0.0153	5630	0.0210	4098	0.0153	5608	0.0209
9	4168	0.0155	5723	0.0213	4155	0.0155	5710	0.0213	4135	0.0154	5675	0.0211	4125	0.0154	5654	0.0210
10	4192	0.0156	5766	0.0215	4180	0.0156	5754	0.0214	4160	0.0155	5719	0.0213	4150	0.0155	5698	0.0212
11	4218	0.0157	5810	0.0216	4205	0.0157	5799	0.0216	4186	0.0156	5764	0.0215	4177	0.0155	5744	0.0214
12	4243	0.0158	5855	0.0218	4231	0.0158	5844	0.0218	4212	0.0157	5810	0.0216	4203	0.0156	5790	0.0216
13	4269	0.0159	5901	0.0220	4258	0.0159	5891	0.0219	4239	0.0158	5857	0.0218	4230	0.0157	5838	0.0217
14	4295	0.0160	5947	0.0221	4285	0.0160	5939	0.0221	4266	0.0159	5904	0.0220	4258	0.0159	5885	0.0219

Table H5: Heat transfer coefficients and Biot number approximations for R3-36 at 7LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3748	0.0140	4727	0.0176	3731	0.0139	4696	0.0175	3728	0.0139	4694	0.0175	3700	0.0138	4654	0.0173
2	3750	0.0140	4730	0.0176	3734	0.0139	4700	0.0175	3732	0.0139	4700	0.0175	3707	0.0138	4664	0.0174
3	3752	0.0140	4733	0.0176	3737	0.0139	4705	0.0175	3735	0.0139	4706	0.0175	3713	0.0138	4674	0.0174
4	3754	0.0140	4736	0.0176	3740	0.0139	4709	0.0175	3739	0.0139	4712	0.0175	3719	0.0138	4683	0.0174
5	3756	0.0140	4740	0.0176	3742	0.0139	4714	0.0175	3743	0.0139	4718	0.0176	3725	0.0139	4693	0.0175
6	3758	0.0140	4743	0.0177	3745	0.0139	4718	0.0176	3746	0.0139	4724	0.0176	3731	0.0139	4703	0.0175
7	3760	0.0140	4746	0.0177	3748	0.0140	4722	0.0176	3750	0.0140	4729	0.0176	3737	0.0139	4713	0.0175
8	3763	0.0140	4750	0.0177	3750	0.0140	4726	0.0176	3753	0.0140	4735	0.0176	3743	0.0139	4723	0.0176
9	3765	0.0140	4754	0.0177	3753	0.0140	4731	0.0176	3757	0.0140	4740	0.0176	3750	0.0140	4733	0.0176
10	3767	0.0140	4757	0.0177	3756	0.0140	4735	0.0176	3760	0.0140	4746	0.0177	3756	0.0140	4743	0.0177
11	3769	0.0140	4760	0.0177	3758	0.0140	4739	0.0176	3763	0.0140	4751	0.0177	3761	0.0140	4752	0.0177
12	3771	0.0140	4764	0.0177	3761	0.0140	4743	0.0177	3767	0.0140	4756	0.0177	3767	0.0140	4760	0.0177
13	3773	0.0140	4767	0.0177	3764	0.0140	4748	0.0177	3770	0.0140	4762	0.0177	3772	0.0140	4770	0.0178
14	3775	0.0141	4770	0.0178	3766	0.0140	4752	0.0177	3773	0.0140	4768	0.0177	3778	0.0141	4779	0.0178
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3678	0.0137	4626	0.0172	3657	0.0136	4591	0.0171	3636	0.0135	4575	0.0170	3602	0.0134	4526	0.0169
2	3687	0.0137	4639	0.0173	3667	0.0137	4607	0.0172	3650	0.0136	4596	0.0171	3619	0.0135	4553	0.0170
3	3695	0.0138	4652	0.0173	3677	0.0137	4623	0.0172	3663	0.0136	4618	0.0172	3637	0.0135	4581	0.0171
4	3703	0.0138	4666	0.0174	3686	0.0137	4638	0.0173	3677	0.0137	4640	0.0173	3655	0.0136	4608	0.0172
5	3712	0.0138	4680	0.0174	3696	0.0138	4654	0.0173	3691	0.0137	4662	0.0174	3672	0.0137	4636	0.0173
6	3721	0.0139	4693	0.0175	3706	0.0138	4670	0.0174	3705	0.0138	4685	0.0174	3689	0.0137	4664	0.0174
7	3729	0.0139	4707	0.0175	3716	0.0138	4686	0.0174	3719	0.0138	4708	0.0175	3707	0.0138	4692	0.0175
8	3738	0.0139	4721	0.0176	3727	0.0139	4703	0.0175	3733	0.0139	4731	0.0176	3725	0.0139	4721	0.0176
9	3747	0.0139	4735	0.0176	3737	0.0139	4719	0.0176	3747	0.0140	4754	0.0177	3743	0.0139	4750	0.0177
10	3755	0.0140	4749	0.0177	3747	0.0140	4736	0.0176	3762	0.0140	4777	0.0178	3761	0.0140	4779	0.0178
11	3764	0.0140	4763	0.0177	3758	0.0140	4753	0.0177	3777	0.0141	4802	0.0179	3779	0.0141	4809	0.0179
12	3772	0.0140	4776	0.0178	3768	0.0140	4769	0.0178	3792	0.0141	4825	0.0180	3798	0.0141	4839	0.0180
13	3780	0.0141	4789	0.0178	3777	0.0141	4784	0.0178	3806	0.0142	4849	0.0181	3816	0.0142	4869	0.0181
14	3788	0.0141	4801	0.0179	3786	0.0141	4799	0.0179	3819	0.0142	4870	0.0181	3833	0.0143	4896	0.0182
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3556	0.0132	4458	0.0166	3525	0.0131	4417	0.0164	3473	0.0129	4325	0.0161	3464	0.0129	4311	0.0161
2	3577	0.0133	4491	0.0167	3548	0.0132	4452	0.0166	3503	0.0130	4374	0.0163	3497	0.0130	4365	0.0163
3	3599	0.0134	4524	0.0168	3572	0.0133	4489	0.0167	3527	0.0131	4411	0.0164	3522	0.0131	4404	0.0164
4	3621	0.0135	4558	0.0170	3596	0.0134	4526	0.0169	3552	0.0132	4449	0.0166	3547	0.0132	4442	0.0165
5	3643	0.0136	4593	0.0171	3620	0.0135	4564	0.0170	3576	0.0133	4487	0.0167	3572	0.0133	4481	0.0167
6	3665	0.0136	4627	0.0172	3644	0.0136	4602	0.0171	3602	0.0134	4526	0.0168	3597	0.0134	4520	0.0168
7	3687	0.0137	4662	0.0174	3669	0.0137	4641	0.0173	3627	0.0135	4565	0.0170	3623	0.0135	4561	0.0170
8	3709	0.0138	4698	0.0175	3693	0.0138	4680	0.0174	3653	0.0136	4606	0.0171	3650	0.0136	4602	0.0171
9	3731	0.0139	4734	0.0176	3718	0.0138	4719	0.0176	3678	0.0137	4646	0.0173	3675	0.0137	4643	0.0173
10	3754	0.0140	4770	0.0178	3743	0.0139	4759	0.0177	3704	0.0138	4687	0.0175	3701	0.0138	4684	0.0174
11	3777	0.0141	4808	0.0179	3768	0.0140	4801	0.0179	3730	0.0139	4729	0.0176	3728	0.0139	4727	0.0176
12	3801	0.0141	4846	0.0180	3794	0.0141	4843	0.0180	3756	0.0140	4772	0.0178	3755	0.0140	4771	0.0178
13	3823	0.0142	4883	0.0182	3821	0.0142	4886	0.0182	3783	0.0141	4816	0.0179	3782	0.0141	4815	0.0179
14	3844	0.0143	4918	0.0183	3845	0.0143	4925	0.0183	3811	0.0142	4860	0.0181	3810	0.0142	4861	0.0181

Table H6: Heat transfer coefficients and Biot number approximations for R3-36 at 5.5LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3247	0.0121	3713	0.0138	3249	0.0121	3717	0.0138	3242	0.0121	3711	0.0138	3231	0.0120	3696	0.0138
2	3249	0.0121	3714	0.0138	3250	0.0121	3720	0.0138	3245	0.0121	3714	0.0138	3235	0.0120	3702	0.0138
3	3250	0.0121	3716	0.0138	3252	0.0121	3722	0.0139	3248	0.0121	3719	0.0138	3239	0.0121	3707	0.0138
4	3251	0.0121	3718	0.0138	3254	0.0121	3725	0.0139	3250	0.0121	3723	0.0139	3242	0.0121	3712	0.0138
5	3252	0.0121	3720	0.0138	3255	0.0121	3727	0.0139	3253	0.0121	3727	0.0139	3246	0.0121	3718	0.0138
6	3254	0.0121	3722	0.0139	3257	0.0121	3729	0.0139	3256	0.0121	3730	0.0139	3250	0.0121	3724	0.0139
7	3255	0.0121	3724	0.0139	3259	0.0121	3732	0.0139	3258	0.0121	3734	0.0139	3254	0.0121	3729	0.0139
8	3256	0.0121	3726	0.0139	3260	0.0121	3734	0.0139	3261	0.0121	3738	0.0139	3257	0.0121	3734	0.0139
9	3258	0.0121	3728	0.0139	3262	0.0121	3737	0.0139	3263	0.0121	3742	0.0139	3261	0.0121	3739	0.0139
10	3259	0.0121	3730	0.0139	3263	0.0121	3739	0.0139	3266	0.0122	3745	0.0139	3264	0.0122	3745	0.0139
11	3260	0.0121	3732	0.0139	3265	0.0122	3741	0.0139	3268	0.0122	3749	0.0140	3268	0.0122	3749	0.0140
12	3262	0.0121	3733	0.0139	3267	0.0122	3744	0.0139	3271	0.0122	3753	0.0140	3271	0.0122	3754	0.0140
13	3263	0.0121	3735	0.0139	3268	0.0122	3746	0.0139	3273	0.0122	3756	0.0140	3274	0.0122	3759	0.0140
14	3264	0.0122	3737	0.0139	3270	0.0122	3749	0.0140	3276	0.0122	3760	0.0140	3278	0.0122	3765	0.0140
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3223	0.0120	3691	0.0137	3220	0.0120	3697	0.0138	3250	0.0121	3772	0.0140	3243	0.0121	3774	0.0141
2	3228	0.0120	3699	0.0138	3228	0.0120	3708	0.0138	3260	0.0121	3787	0.0141	3255	0.0121	3793	0.0141
3	3234	0.0120	3707	0.0138	3235	0.0120	3718	0.0138	3270	0.0122	3802	0.0142	3268	0.0122	3812	0.0142
4	3239	0.0121	3715	0.0138	3242	0.0121	3729	0.0139	3280	0.0122	3817	0.0142	3281	0.0122	3830	0.0143
5	3245	0.0121	3723	0.0139	3249	0.0121	3739	0.0139	3290	0.0122	3832	0.0143	3294	0.0123	3850	0.0143
6	3250	0.0121	3731	0.0139	3257	0.0121	3750	0.0140	3300	0.0123	3847	0.0143	3307	0.0123	3869	0.0144
7	3256	0.0121	3739	0.0139	3264	0.0122	3761	0.0140	3311	0.0123	3863	0.0144	3320	0.0124	3889	0.0145
8	3261	0.0121	3747	0.0140	3271	0.0122	3772	0.0140	3321	0.0124	3878	0.0144	3333	0.0124	3908	0.0146
9	3267	0.0122	3755	0.0140	3279	0.0122	3783	0.0141	3332	0.0124	3894	0.0145	3347	0.0125	3929	0.0146
10	3272	0.0122	3763	0.0140	3286	0.0122	3794	0.0141	3343	0.0124	3910	0.0146	3360	0.0125	3949	0.0147
11	3277	0.0122	3771	0.0140	3294	0.0123	3805	0.0142	3354	0.0125	3926	0.0146	3374	0.0126	3970	0.0148
12	3282	0.0122	3778	0.0141	3300	0.0123	3815	0.0142	3364	0.0125	3942	0.0147	3388	0.0126	3990	0.0149
13	3287	0.0122	3785	0.0141	3307	0.0123	3824	0.0142	3374	0.0126	3956	0.0147	3400	0.0127	4009	0.0149
14	3292	0.0123	3793	0.0141	3313	0.0123	3834	0.0143	3383	0.0126	3971	0.0148	3413	0.0127	4028	0.0150
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3237	0.0121	3791	0.0141	3165	0.0118	3678	0.0137	3115	0.0116	3598	0.0134	3115	0.0116	3604	0.0134
2	3255	0.0121	3817	0.0142	3187	0.0119	3709	0.0138	3141	0.0117	3637	0.0135	3146	0.0117	3653	0.0136
3	3273	0.0122	3843	0.0143	3209	0.0119	3741	0.0139	3164	0.0118	3671	0.0137	3170	0.0118	3687	0.0137
4	3292	0.0123	3870	0.0144	3232	0.0120	3773	0.0140	3188	0.0119	3704	0.0138	3194	0.0119	3721	0.0139
5	3310	0.0123	3897	0.0145	3255	0.0121	3807	0.0142	3212	0.0120	3739	0.0139	3218	0.0120	3756	0.0140
6	3328	0.0124	3924	0.0146	3278	0.0122	3840	0.0143	3237	0.0121	3775	0.0141	3243	0.0121	3793	0.0141
7	3346	0.0125	3951	0.0147	3301	0.0123	3874	0.0144	3262	0.0121	3810	0.0142	3269	0.0122	3830	0.0143
8	3365	0.0125	3979	0.0148	3324	0.0124	3908	0.0146	3286	0.0122	3846	0.0143	3294	0.0123	3866	0.0144
9	3384	0.0126	4008	0.0149	3348	0.0125	3944	0.0147	3310	0.0123	3883	0.0145	3319	0.0124	3904	0.0145
10	3403	0.0127	4037	0.0150	3371	0.0126	3979	0.0148	3336	0.0124	3920	0.0146	3345	0.0125	3942	0.0147
11	3422	0.0127	4066	0.0151	3396	0.0126	4016	0.0150	3361	0.0125	3959	0.0147	3371	0.0126	3981	0.0148
12	3442	0.0128	4095	0.0152	3420	0.0127	4053	0.0151	3387	0.0126	3998	0.0149	3398	0.0126	4022	0.0150
13	3459	0.0129	4122	0.0153	3442	0.0128	4087	0.0152	3413	0.0127	4036	0.0150	3425	0.0128	4063	0.0151
14	3477	0.0129	4149	0.0154	3465	0.0129	4121	0.0153	3437	0.0128	4072	0.0152	3449	0.0128	4100	0.0153

Table H7: Heat transfer coefficients and Biot number approximations for R3-60 at 14LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4902	0.0183	7432	0.0277	5098	0.0190	7941	0.0296	5212	0.0194	8250	0.0307	5147	0.0192	8125	0.0302
2	4904	0.0183	7435	0.0277	5100	0.0190	7944	0.0296	5214	0.0194	8255	0.0307	5153	0.0192	8136	0.0303
3	4905	0.0183	7438	0.0277	5102	0.0190	7948	0.0296	5217	0.0194	8261	0.0308	5158	0.0192	8147	0.0303
4	4907	0.0183	7441	0.0277	5104	0.0190	7952	0.0296	5220	0.0194	8267	0.0308	5164	0.0192	8158	0.0304
5	4908	0.0183	7444	0.0277	5105	0.0190	7955	0.0296	5222	0.0194	8271	0.0308	5169	0.0192	8169	0.0304
6	4910	0.0183	7447	0.0277	5107	0.0190	7959	0.0296	5225	0.0195	8276	0.0308	5175	0.0193	8180	0.0305
7	4911	0.0183	7450	0.0277	5109	0.0190	7963	0.0296	5227	0.0195	8281	0.0308	5180	0.0193	8191	0.0305
8	4913	0.0183	7453	0.0277	5111	0.0190	7967	0.0297	5230	0.0195	8286	0.0308	5186	0.0193	8203	0.0305
9	4914	0.0183	7456	0.0278	5113	0.0190	7971	0.0297	5232	0.0195	8291	0.0309	5191	0.0193	8214	0.0306
10	4916	0.0183	7459	0.0278	5114	0.0190	7974	0.0297	5234	0.0195	8296	0.0309	5197	0.0193	8225	0.0306
11	4917	0.0183	7462	0.0278	5116	0.0190	7978	0.0297	5237	0.0195	8301	0.0309	5202	0.0194	8236	0.0307
12	4919	0.0183	7465	0.0278	5118	0.0191	7982	0.0297	5239	0.0195	8306	0.0309	5208	0.0194	8247	0.0307
13	4920	0.0183	7467	0.0278	5120	0.0191	7985	0.0297	5241	0.0195	8310	0.0309	5214	0.0194	8259	0.0307
14	4922	0.0183	7470	0.0278	5122	0.0191	7989	0.0297	5244	0.0195	8315	0.0310	5219	0.0194	8270	0.0308
15	4923	0.0183	7473	0.0278	5124	0.0191	7993	0.0298	5246	0.0195	8320	0.0310	5225	0.0195	8281	0.0308
16	4925	0.0183	7476	0.0278	5126	0.0191	7996	0.0298	5249	0.0195	8325	0.0310	5230	0.0195	8292	0.0309
17	4926	0.0183	7479	0.0278	5128	0.0191	8000	0.0298	5251	0.0196	8330	0.0310	5235	0.0195	8302	0.0309
18	4928	0.0183	7482	0.0279	5130	0.0191	8004	0.0298	5254	0.0196	8335	0.0310	5240	0.0195	8313	0.0309
19	4929	0.0184	7485	0.0279	5131	0.0191	8007	0.0298	5256	0.0196	8340	0.0311	5245	0.0195	8323	0.0310
20	4931	0.0184	7488	0.0279	5133	0.0191	8012	0.0298	5259	0.0196	8345	0.0311	5250	0.0195	8333	0.0310
21	4932	0.0184	7491	0.0279	5135	0.0191	8015	0.0298	5261	0.0196	8349	0.0311	5255	0.0196	8343	0.0311
22	4934	0.0184	7494	0.0279	5137	0.0191	8019	0.0299	5263	0.0196	8354	0.0311	5260	0.0196	8353	0.0311
23	4936	0.0184	7497	0.0279	5139	0.0191	8023	0.0299	5266	0.0196	8359	0.0311	5266	0.0196	8364	0.0311
24	4937	0.0184	7500	0.0279	5141	0.0191	8026	0.0299	5268	0.0196	8365	0.0311	5271	0.0196	8374	0.0312
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	5024	0.0187	7878	0.0293	4972	0.0185	7772	0.0289	4859	0.0181	7544	0.0281	4963	0.0185	7854	0.0292
2	5034	0.0187	7897	0.0294	4984	0.0186	7795	0.0290	4876	0.0182	7576	0.0282	4982	0.0185	7892	0.0294
3	5044	0.0188	7917	0.0295	4996	0.0186	7819	0.0291	4893	0.0182	7608	0.0283	5001	0.0186	7929	0.0295
4	5054	0.0188	7938	0.0296	5009	0.0186	7844	0.0292	4909	0.0183	7640	0.0284	5021	0.0187	7967	0.0297
5	5064	0.0189	7957	0.0296	5020	0.0187	7867	0.0293	4927	0.0183	7673	0.0286	5041	0.0188	8006	0.0298
6	5074	0.0189	7978	0.0297	5033	0.0187	7891	0.0294	4944	0.0184	7706	0.0287	5060	0.0188	8045	0.0300
7	5084	0.0189	7997	0.0298	5044	0.0188	7914	0.0295	4961	0.0185	7739	0.0288	5080	0.0189	8084	0.0301
8	5095	0.0190	8018	0.0299	5057	0.0188	7939	0.0296	4979	0.0185	7773	0.0289	5101	0.0190	8124	0.0302
9	5105	0.0190	8039	0.0299	5069	0.0189	7964	0.0296	4995	0.0186	7806	0.0291	5121	0.0191	8164	0.0304
10	5115	0.0190	8059	0.0300	5081	0.0189	7988	0.0297	5012	0.0187	7840	0.0292	5142	0.0191	8205	0.0305
11	5126	0.0191	8080	0.0301	5094	0.0190	8013	0.0298	5029	0.0187	7873	0.0293	5162	0.0192	8246	0.0307
12	5136	0.0191	8101	0.0302	5106	0.0190	8038	0.0299	5046	0.0188	7907	0.0294	5182	0.0193	8286	0.0308
13	5146	0.0192	8122	0.0302	5119	0.0191	8063	0.0300	5064	0.0189	7942	0.0296	5202	0.0194	8327	0.0310
14	5157	0.0192	8143	0.0303	5131	0.0191	8088	0.0301	5081	0.0189	7976	0.0297	5222	0.0194	8368	0.0312
15	5168	0.0192	8165	0.0304	5144	0.0192	8114	0.0302	5098	0.0190	8011	0.0298	5243	0.0195	8410	0.0313
16	5178	0.0193	8186	0.0305	5157	0.0192	8139	0.0303	5116	0.0190	8047	0.0300	5264	0.0196	8452	0.0315
17	5189	0.0193	8208	0.0306	5170	0.0192	8165	0.0304	5134	0.0191	8082	0.0301	5285	0.0197	8495	0.0316
18	5200	0.0194	8230	0.0306	5183	0.0193	8192	0.0305	5152	0.0192	8118	0.0302	5306	0.0198	8539	0.0318
19	5211	0.0194	8251	0.0307	5196	0.0193	8217	0.0306	5171	0.0193	8155	0.0304	5328	0.0198	8583	0.0320
20	5222	0.0194	8274	0.0308	5209	0.0194	8244	0.0307	5189	0.0193	8192	0.0305	5349	0.0199	8627	0.0321
21	5232	0.0195	8294	0.0309	5222	0.0194	8270	0.0308	5207	0.0194	8229	0.0306	5371	0.0200	8673	0.0323
22	5242	0.0195	8314	0.0310	5234	0.0195	8294	0.0309	5223	0.0194	8262	0.0308	5391	0.0201	8713	0.0324
23	5251	0.0196	8334	0.0310	5245	0.0195	8318	0.0310	5240	0.0195	8295	0.0309	5410	0.0201	8753	0.0326
24	5261	0.0196	8353	0.0311	5257	0.0196	8342	0.0311	5257	0.0196	8330	0.0310	5430	0.0202	8795	0.0327
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4886	0.0182	7684	0.0286	4775	0.0178	7413	0.0276	4748	0.0177	7351	0.0274	4756	0.0177	7378	0.0275
2	4913	0.0183	7740	0.0288	4802	0.0179	7470	0.0278	4775	0.0178	7408	0.0276	4783	0.0178	7433	0.0277
3	4933	0.0184	7779	0.0290	4830	0.0180	7526	0.0280	4803	0.0179	7465	0.0278	4811	0.0179	7491	0.0279
4	4953	0.0184	7818	0.0291	4852	0.0181	7570	0.0282	4830	0.0180	7521	0.0280	4840	0.0180	7551	0.0281
5	4973	0.0185	7858	0.0293	4872	0.0181	7609	0.0283	4850	0.0181	7560	0.0281	4861	0.0181	7592	0.0283
6	4994	0.0186	7898	0.0294	4892	0.0182	7648	0.0285	4871	0.0181	7601	0.0283	4882	0.0182	7632	0.0284
7	5015	0.0187	7939	0.0296	4913	0.0183	7689	0.0286	4892	0.0182	7641	0.0284	4903	0.0183	7673	0.0286
8	5036	0.0187	7980	0.0297	4934	0.0184	7729	0.0288	4913	0.0183	7682	0.0286	4924	0.0183	7714	0.0287
9	5057	0.0188	8021	0.0299	4955	0.0184	7770	0.0289	4935	0.0184	7723	0.0288	4946	0.0184	7755	0.0289
10	5078	0.0189	8063	0.0300	4977	0.0185	7811	0.0291	4956	0.0185	7765	0.0289	4968	0.0185	7798	0.0290
11	5100	0.0190	8106	0.0302	4998	0.0186	7853	0.0292	4978	0.0185	7807	0.0291	4990	0.0186	7841	0.0292
12	5122	0.0191	8149	0.0303	5020	0.0187	7896	0.0294	5000	0.0186	7850	0.0292	5012	0.0187	7884	0.0294
13	5143	0.0191	8191	0.0305	5042	0.0188	7938	0.0296	5023	0.0187	7894	0.0294	5034	0.0187	7927	0.0295
14	5164	0.0192	8234	0.0307	5064	0.0189	7981	0.0297	5045	0.0188	7937	0.0295	5057	0.0188	7971	

Table H8: Heat transfer coefficients and Biot number approximations for R3-60 at 12LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4842	0.0180	7269	0.0271	4872	0.0181	7348	0.0274	4819	0.0179	7243	0.0270	4784	0.0178	7189	0.0268
2	4843	0.0180	7271	0.0271	4872	0.0181	7349	0.0274	4823	0.0180	7250	0.0270	4790	0.0178	7199	0.0268
3	4843	0.0180	7272	0.0271	4874	0.0181	7352	0.0274	4826	0.0180	7256	0.0270	4795	0.0179	7208	0.0268
4	4844	0.0180	7273	0.0271	4874	0.0181	7353	0.0274	4829	0.0180	7261	0.0270	4800	0.0179	7219	0.0269
5	4845	0.0180	7275	0.0271	4876	0.0182	7355	0.0274	4832	0.0180	7268	0.0271	4805	0.0179	7229	0.0269
6	4846	0.0180	7276	0.0271	4876	0.0182	7357	0.0274	4835	0.0180	7274	0.0271	4811	0.0179	7240	0.0270
7	4846	0.0180	7277	0.0271	4877	0.0182	7359	0.0274	4838	0.0180	7279	0.0271	4816	0.0179	7250	0.0270
8	4847	0.0180	7279	0.0271	4878	0.0182	7361	0.0274	4841	0.0180	7286	0.0271	4821	0.0180	7260	0.0270
9	4848	0.0180	7280	0.0271	4879	0.0182	7363	0.0274	4844	0.0180	7292	0.0271	4827	0.0180	7270	0.0271
10	4848	0.0181	7282	0.0271	4880	0.0182	7365	0.0274	4847	0.0180	7297	0.0272	4832	0.0180	7281	0.0271
11	4849	0.0181	7283	0.0271	4881	0.0182	7366	0.0274	4850	0.0181	7303	0.0272	4838	0.0180	7291	0.0271
12	4850	0.0181	7284	0.0271	4882	0.0182	7369	0.0274	4853	0.0181	7308	0.0272	4843	0.0180	7302	0.0272
13	4851	0.0181	7286	0.0271	4883	0.0182	7370	0.0274	4856	0.0181	7313	0.0272	4849	0.0181	7312	0.0272
14	4851	0.0181	7287	0.0271	4884	0.0182	7372	0.0274	4858	0.0181	7318	0.0272	4854	0.0181	7323	0.0273
15	4852	0.0181	7289	0.0271	4885	0.0182	7374	0.0275	4861	0.0181	7324	0.0273	4860	0.0181	7333	0.0273
16	4853	0.0181	7290	0.0271	4886	0.0182	7376	0.0275	4864	0.0181	7329	0.0273	4865	0.0181	7344	0.0273
17	4854	0.0181	7292	0.0271	4887	0.0182	7378	0.0275	4867	0.0181	7334	0.0273	4870	0.0181	7354	0.0274
18	4855	0.0181	7293	0.0272	4888	0.0182	7380	0.0275	4870	0.0181	7340	0.0273	4875	0.0181	7363	0.0274
19	4855	0.0181	7294	0.0272	4889	0.0182	7382	0.0275	4872	0.0181	7345	0.0273	4880	0.0182	7372	0.0274
20	4856	0.0181	7296	0.0272	4890	0.0182	7384	0.0275	4875	0.0181	7351	0.0274	4885	0.0182	7382	0.0275
21	4856	0.0181	7297	0.0272	4891	0.0182	7386	0.0275	4878	0.0182	7357	0.0274	4890	0.0182	7391	0.0275
22	4857	0.0181	7298	0.0272	4892	0.0182	7387	0.0275	4881	0.0182	7362	0.0274	4895	0.0182	7401	0.0275
23	4858	0.0181	7300	0.0272	4893	0.0182	7390	0.0275	4883	0.0182	7367	0.0274	4899	0.0182	7410	0.0276
24	4859	0.0181	7301	0.0272	4894	0.0182	7391	0.0275	4886	0.0182	7373	0.0274	4904	0.0183	7420	0.0276
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4702	0.0175	7041	0.0262	4661	0.0174	6975	0.0260	4611	0.0172	6891	0.0257	4569	0.0170	6818	0.0254
2	4711	0.0175	7058	0.0263	4674	0.0174	6997	0.0261	4626	0.0172	6919	0.0258	4587	0.0171	6851	0.0255
3	4720	0.0176	7075	0.0263	4686	0.0174	7020	0.0261	4642	0.0173	6949	0.0259	4605	0.0171	6885	0.0256
4	4730	0.0176	7093	0.0264	4698	0.0175	7042	0.0262	4658	0.0173	6978	0.0260	4623	0.0172	6918	0.0258
5	4739	0.0176	7110	0.0265	4709	0.0175	7065	0.0263	4673	0.0174	7007	0.0261	4642	0.0173	6952	0.0259
6	4748	0.0177	7128	0.0265	4721	0.0176	7087	0.0264	4690	0.0175	7037	0.0262	4660	0.0174	6987	0.0260
7	4757	0.0177	7145	0.0266	4734	0.0176	7111	0.0265	4706	0.0175	7067	0.0263	4679	0.0174	7022	0.0261
8	4767	0.0177	7163	0.0267	4745	0.0177	7133	0.0266	4721	0.0176	7097	0.0264	4698	0.0175	7057	0.0263
9	4776	0.0178	7181	0.0267	4758	0.0177	7156	0.0266	4737	0.0176	7127	0.0265	4718	0.0176	7093	0.0264
10	4785	0.0178	7199	0.0268	4770	0.0178	7179	0.0267	4753	0.0177	7156	0.0266	4736	0.0176	7127	0.0265
11	4795	0.0179	7217	0.0269	4782	0.0178	7203	0.0268	4769	0.0178	7187	0.0268	4754	0.0177	7163	0.0267
12	4804	0.0179	7236	0.0269	4794	0.0178	7226	0.0269	4785	0.0178	7218	0.0269	4773	0.0178	7199	0.0268
13	4814	0.0179	7255	0.0270	4806	0.0179	7250	0.0270	4801	0.0179	7249	0.0270	4792	0.0178	7236	0.0269
14	4824	0.0180	7273	0.0271	4819	0.0179	7274	0.0271	4817	0.0179	7280	0.0271	4811	0.0179	7272	0.0271
15	4834	0.0180	7292	0.0271	4831	0.0180	7298	0.0272	4834	0.0180	7312	0.0272	4831	0.0180	7310	0.0272
16	4844	0.0180	7311	0.0272	4844	0.0180	7322	0.0273	4850	0.0181	7344	0.0273	4850	0.0181	7347	0.0274
17	4853	0.0181	7329	0.0273	4857	0.0181	7347	0.0274	4867	0.0181	7376	0.0275	4870	0.0181	7385	0.0275
18	4863	0.0181	7348	0.0274	4870	0.0181	7371	0.0274	4884	0.0182	7409	0.0276	4890	0.0182	7424	0.0276
19	4873	0.0181	7367	0.0274	4883	0.0182	7397	0.0275	4901	0.0182	7442	0.0277	4910	0.0183	7463	0.0278
20	4883	0.0182	7386	0.0275	4896	0.0182	7422	0.0276	4918	0.0183	7474	0.0278	4929	0.0184	7500	0.0279
21	4891	0.0182	7403	0.0276	4907	0.0183	7445	0.0277	4933	0.0184	7503	0.0279	4947	0.0184	7536	0.0281
22	4900	0.0182	7420	0.0276	4919	0.0183	7467	0.0278	4948	0.0184	7534	0.0280	4965	0.0185	7571	0.0282
23	4909	0.0183	7437	0.0277	4931	0.0184	7490	0.0279	4964	0.0185	7564	0.0282	4984	0.0186	7607	0.0283
24	4918	0.0183	7454	0.0278	4942	0.0184	7512	0.0280	4979	0.0185	7594	0.0283	5003	0.0186	7644	0.0285
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4547	0.0169	6794	0.0253	4473	0.0167	6629	0.0247	4463	0.0166	6615	0.0246	4467	0.0166	6629	0.0247
2	4566	0.0170	6830	0.0254	4500	0.0168	6682	0.0249	4489	0.0167	6668	0.0248	4494	0.0167	6682	0.0249
3	4586	0.0171	6866	0.0256	4521	0.0168	6722	0.0250	4517	0.0168	6723	0.0250	4521	0.0168	6736	0.0251
4	4605	0.0171	6902	0.0257	4540	0.0169	6758	0.0252	4537	0.0169	6759	0.0252	4543	0.0169	6778	0.0252
5	4625	0.0172	6939	0.0258	4560	0.0170	6794	0.0253	4557	0.0170	6796	0.0253	4563	0.0170	6815	0.0254
6	4645	0.0173	6976	0.0260	4580	0.0171	6832	0.0254	4577	0.0170	6833	0.0254	4584	0.0171	6853	0.0255
7	4666	0.0174	7014	0.0261	4600	0.0171	6869	0.0256	4598	0.0171	6871	0.0256	4605	0.0171	6891	0.0257
8	4686	0.0174	7052	0.0263	4621	0.0172	6906	0.0257	4618	0.0172	6909	0.0257	4625	0.0172	6930	0.0258
9	4707	0.0175	7091	0.0264	4642	0.0173	6945	0.0259	4639	0.0173	6948	0.0259	4647	0.0173	6969	0.0259
10	4728	0.0176	7130	0.0265	4663	0.0174	6983	0.0260	4660	0.0174	6987	0.0260	4668	0.0174	7009	0.0261
11	4749	0.0177	7168	0.0267	4684	0.0174	7022	0.0261	4682	0.0174	7027	0.0262	4690	0.0175	7049	0.0262
12	4769	0.0178	7207	0.0268	4705	0.0175	7062	0.0263	4704	0.0175	7067	0.0263	4712	0.0175	7090	0.0264
13	4790	0.0178	7247	0.0270	4726	0.0176	7101	0.0264	4725	0.0176	7107	0.0265	4733	0.0176	7130	0.0265
14	4810	0.0179	7287	0.0271	4746	0.0177	7140	0.0266	4746	0.0177	7147	0.0266	4755	0.0177	7171	

Table H9: Heat transfer coefficients and Biot number approximations for R3-60 at 10LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4482	0.0167	6391	0.0238	4484	0.0167	6403	0.0238	4469	0.0166	6376	0.0237	4430	0.0165	6308	0.0235
2	4483	0.0167	6393	0.0238	4486	0.0167	6406	0.0239	4472	0.0166	6381	0.0238	4435	0.0165	6316	0.0235
3	4485	0.0167	6396	0.0238	4488	0.0167	6410	0.0239	4475	0.0167	6386	0.0238	4439	0.0165	6324	0.0235
4	4486	0.0167	6398	0.0238	4490	0.0167	6413	0.0239	4477	0.0167	6391	0.0238	4444	0.0165	6333	0.0236
5	4488	0.0167	6402	0.0238	4492	0.0167	6417	0.0239	4480	0.0167	6396	0.0238	4448	0.0166	6341	0.0236
6	4489	0.0167	6404	0.0238	4494	0.0167	6420	0.0239	4483	0.0167	6401	0.0238	4453	0.0166	6350	0.0236
7	4491	0.0167	6407	0.0239	4496	0.0167	6424	0.0239	4486	0.0167	6406	0.0239	4457	0.0166	6357	0.0237
8	4492	0.0167	6409	0.0239	4498	0.0167	6427	0.0239	4489	0.0167	6412	0.0239	4462	0.0166	6366	0.0237
9	4493	0.0167	6412	0.0239	4499	0.0168	6430	0.0239	4491	0.0167	6416	0.0239	4467	0.0166	6374	0.0237
10	4495	0.0167	6414	0.0239	4501	0.0168	6434	0.0240	4493	0.0167	6421	0.0239	4471	0.0166	6383	0.0238
11	4496	0.0167	6417	0.0239	4503	0.0168	6437	0.0240	4496	0.0167	6425	0.0239	4476	0.0167	6391	0.0238
12	4498	0.0167	6420	0.0239	4505	0.0168	6440	0.0240	4498	0.0167	6430	0.0239	4481	0.0167	6400	0.0238
13	4499	0.0168	6423	0.0239	4507	0.0168	6444	0.0240	4501	0.0168	6435	0.0240	4485	0.0167	6408	0.0239
14	4501	0.0168	6425	0.0239	4509	0.0168	6448	0.0240	4504	0.0168	6439	0.0240	4490	0.0167	6417	0.0239
15	4502	0.0168	6428	0.0239	4511	0.0168	6451	0.0240	4506	0.0168	6444	0.0240	4494	0.0167	6424	0.0239
16	4504	0.0168	6431	0.0239	4513	0.0168	6455	0.0240	4509	0.0168	6448	0.0240	4498	0.0167	6432	0.0239
17	4505	0.0168	6433	0.0240	4515	0.0168	6458	0.0240	4511	0.0168	6453	0.0240	4502	0.0168	6439	0.0240
18	4506	0.0168	6436	0.0240	4516	0.0168	6461	0.0241	4514	0.0168	6458	0.0240	4507	0.0168	6447	0.0240
19	4508	0.0168	6438	0.0240	4518	0.0168	6465	0.0241	4516	0.0168	6463	0.0241	4510	0.0168	6454	0.0240
20	4509	0.0168	6441	0.0240	4520	0.0168	6468	0.0241	4519	0.0168	6467	0.0241	4515	0.0168	6462	0.0241
21	4511	0.0168	6444	0.0240	4522	0.0168	6472	0.0241	4521	0.0168	6472	0.0241	4519	0.0168	6470	0.0241
22	4513	0.0168	6447	0.0240	4524	0.0168	6476	0.0241	4524	0.0168	6476	0.0241	4523	0.0168	6478	0.0241
23	4514	0.0168	6449	0.0240	4526	0.0169	6479	0.0241	4527	0.0169	6482	0.0241	4527	0.0169	6485	0.0241
24	4515	0.0168	6452	0.0240	4528	0.0169	6483	0.0241	4529	0.0169	6486	0.0241	4531	0.0169	6493	0.0242
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4357	0.0162	6172	0.0230	4305	0.0160	6079	0.0226	4242	0.0158	5978	0.0223	4187	0.0156	5877	0.0219
2	4364	0.0162	6184	0.0230	4315	0.0161	6096	0.0227	4255	0.0158	6002	0.0223	4203	0.0156	5904	0.0220
3	4371	0.0163	6196	0.0231	4324	0.0161	6112	0.0228	4269	0.0159	6026	0.0224	4219	0.0157	5932	0.0221
4	4378	0.0163	6209	0.0231	4333	0.0161	6129	0.0228	4283	0.0159	6050	0.0225	4235	0.0158	5960	0.0222
5	4385	0.0163	6222	0.0232	4342	0.0162	6145	0.0229	4297	0.0160	6074	0.0226	4252	0.0158	5988	0.0223
6	4392	0.0164	6235	0.0232	4351	0.0162	6162	0.0229	4311	0.0160	6099	0.0227	4268	0.0159	6016	0.0224
7	4400	0.0164	6248	0.0233	4361	0.0162	6179	0.0230	4324	0.0161	6122	0.0228	4284	0.0160	6045	0.0225
8	4406	0.0164	6260	0.0233	4370	0.0163	6195	0.0231	4338	0.0161	6147	0.0229	4301	0.0160	6074	0.0226
9	4414	0.0164	6273	0.0234	4380	0.0163	6213	0.0231	4351	0.0162	6171	0.0230	4317	0.0161	6103	0.0227
10	4421	0.0165	6286	0.0234	4389	0.0163	6230	0.0232	4365	0.0163	6196	0.0231	4333	0.0161	6132	0.0228
11	4428	0.0165	6300	0.0235	4398	0.0164	6247	0.0233	4379	0.0163	6221	0.0232	4350	0.0162	6161	0.0229
12	4436	0.0165	6313	0.0235	4408	0.0164	6264	0.0233	4393	0.0164	6246	0.0233	4366	0.0163	6191	0.0231
13	4443	0.0165	6326	0.0236	4418	0.0164	6282	0.0234	4406	0.0164	6271	0.0233	4383	0.0163	6221	0.0232
14	4450	0.0166	6339	0.0236	4427	0.0165	6299	0.0235	4421	0.0165	6297	0.0234	4400	0.0164	6251	0.0233
15	4457	0.0166	6352	0.0237	4437	0.0165	6317	0.0235	4435	0.0165	6323	0.0235	4417	0.0164	6282	0.0234
16	4465	0.0166	6366	0.0237	4447	0.0166	6334	0.0236	4449	0.0166	6349	0.0236	4434	0.0165	6313	0.0235
17	4472	0.0167	6380	0.0238	4457	0.0166	6353	0.0237	4464	0.0166	6375	0.0237	4451	0.0166	6344	0.0236
18	4480	0.0167	6393	0.0238	4467	0.0166	6370	0.0237	4479	0.0167	6402	0.0238	4469	0.0166	6376	0.0237
19	4486	0.0167	6405	0.0238	4477	0.0167	6388	0.0238	4493	0.0167	6429	0.0239	4486	0.0167	6409	0.0239
20	4493	0.0167	6417	0.0239	4486	0.0167	6406	0.0239	4507	0.0168	6454	0.0240	4502	0.0168	6437	0.0240
21	4500	0.0168	6429	0.0239	4495	0.0167	6422	0.0239	4521	0.0168	6479	0.0241	4518	0.0168	6466	0.0241
22	4506	0.0168	6442	0.0240	4504	0.0168	6439	0.0240	4534	0.0169	6503	0.0242	4534	0.0169	6496	0.0242
23	4513	0.0168	6453	0.0240	4513	0.0168	6455	0.0240	4547	0.0169	6527	0.0243	4550	0.0169	6526	0.0243
24	4519	0.0168	6466	0.0241	4522	0.0168	6472	0.0241	4561	0.0170	6553	0.0244	4566	0.0170	6555	0.0244
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4138	0.0154	5796	0.0216	4081	0.0152	5687	0.0212	4053	0.0151	5635	0.0210	4057	0.0151	5648	0.0210
2	4156	0.0155	5828	0.0217	4107	0.0153	5735	0.0214	4079	0.0152	5683	0.0212	4084	0.0152	5697	0.0212
3	4175	0.0155	5860	0.0218	4129	0.0154	5775	0.0215	4106	0.0153	5732	0.0213	4110	0.0153	5747	0.0214
4	4193	0.0156	5892	0.0219	4149	0.0154	5808	0.0216	4129	0.0154	5775	0.0215	4136	0.0154	5794	0.0216
5	4212	0.0157	5925	0.0221	4168	0.0155	5842	0.0217	4149	0.0154	5808	0.0216	4156	0.0155	5828	0.0217
6	4232	0.0158	5959	0.0222	4188	0.0156	5876	0.0219	4168	0.0155	5842	0.0218	4176	0.0155	5863	0.0218
7	4251	0.0158	5992	0.0223	4207	0.0157	5910	0.0220	4189	0.0156	5878	0.0219	4196	0.0156	5898	0.0220
8	4271	0.0159	6027	0.0224	4227	0.0157	5945	0.0221	4209	0.0157	5913	0.0220	4217	0.0157	5934	0.0221
9	4290	0.0160	6061	0.0226	4248	0.0158	5980	0.0223	4230	0.0157	5949	0.0221	4237	0.0158	5970	0.0222
10	4311	0.0160	6096	0.0227	4268	0.0159	6016	0.0224	4250	0.0158	5985	0.0223	4259	0.0159	6007	0.0224
11	4330	0.0161	6131	0.0228	4289	0.0160	6052	0.0225	4271	0.0159	6021	0.0224	4280	0.0159	6044	0.0225
12	4349	0.0162	6165	0.0230	4310	0.0160	6088	0.0227	4293	0.0160	6059	0.0226	4301	0.0160	6081	0.0226
13	4369	0.0163	6201	0.0231	4330	0.0161	6125	0.0228	4313	0.0161	6095	0.0227	4323	0.0161	6119	0.0228
14	4389	0.0163	6237	0.0232	4351	0.0162	6162	0.0229	4334	0.0161	6133	0.0228	4344	0.0162		

Table H10: Heat transfer coefficients and Biot number approximations for R3-60 at 9LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4239	0.0158	5826	0.0217	4226	0.0157	5805	0.0216	4213	0.0157	5785	0.0215	4192	0.0156	5759	0.0214
2	4240	0.0158	5828	0.0217	4228	0.0157	5809	0.0216	4216	0.0157	5790	0.0216	4197	0.0156	5767	0.0215
3	4241	0.0158	5830	0.0217	4230	0.0157	5813	0.0216	4218	0.0157	5794	0.0216	4202	0.0156	5775	0.0215
4	4243	0.0158	5832	0.0217	4232	0.0158	5817	0.0217	4221	0.0157	5800	0.0216	4206	0.0157	5783	0.0215
5	4244	0.0158	5834	0.0217	4235	0.0158	5820	0.0217	4224	0.0157	5805	0.0216	4210	0.0157	5791	0.0216
6	4245	0.0158	5837	0.0217	4237	0.0158	5824	0.0217	4227	0.0157	5810	0.0216	4215	0.0157	5798	0.0216
7	4246	0.0158	5838	0.0217	4239	0.0158	5828	0.0217	4230	0.0157	5815	0.0217	4219	0.0157	5807	0.0216
8	4248	0.0158	5841	0.0217	4241	0.0158	5832	0.0217	4233	0.0158	5820	0.0217	4224	0.0157	5814	0.0216
9	4249	0.0158	5843	0.0218	4243	0.0158	5836	0.0217	4236	0.0158	5825	0.0217	4228	0.0157	5822	0.0217
10	4250	0.0158	5845	0.0218	4245	0.0158	5839	0.0217	4239	0.0158	5830	0.0217	4233	0.0158	5830	0.0217
11	4251	0.0158	5847	0.0218	4247	0.0158	5842	0.0218	4242	0.0158	5836	0.0217	4238	0.0158	5838	0.0217
12	4253	0.0158	5850	0.0218	4249	0.0158	5846	0.0218	4245	0.0158	5841	0.0217	4242	0.0158	5846	0.0218
13	4254	0.0158	5852	0.0218	4251	0.0158	5849	0.0218	4247	0.0158	5845	0.0218	4247	0.0158	5854	0.0218
14	4255	0.0158	5854	0.0218	4253	0.0158	5853	0.0218	4250	0.0158	5850	0.0218	4251	0.0158	5862	0.0218
15	4256	0.0158	5856	0.0218	4255	0.0158	5855	0.0218	4253	0.0158	5855	0.0218	4256	0.0158	5870	0.0219
16	4258	0.0159	5858	0.0218	4257	0.0158	5859	0.0218	4256	0.0158	5860	0.0218	4260	0.0159	5878	0.0219
17	4259	0.0159	5861	0.0218	4259	0.0159	5863	0.0218	4258	0.0159	5864	0.0218	4265	0.0159	5886	0.0219
18	4260	0.0159	5863	0.0218	4261	0.0159	5866	0.0218	4260	0.0159	5868	0.0218	4269	0.0159	5894	0.0219
19	4261	0.0159	5865	0.0218	4262	0.0159	5869	0.0219	4263	0.0159	5873	0.0219	4273	0.0159	5901	0.0220
20	4263	0.0159	5867	0.0218	4264	0.0159	5873	0.0219	4266	0.0159	5878	0.0219	4277	0.0159	5908	0.0220
21	4264	0.0159	5870	0.0219	4266	0.0159	5876	0.0219	4268	0.0159	5883	0.0219	4281	0.0159	5916	0.0220
22	4265	0.0159	5872	0.0219	4268	0.0159	5880	0.0219	4271	0.0159	5887	0.0219	4285	0.0160	5923	0.0221
23	4266	0.0159	5874	0.0219	4270	0.0159	5883	0.0219	4274	0.0159	5891	0.0219	4290	0.0160	5930	0.0221
24	4268	0.0159	5876	0.0219	4272	0.0159	5886	0.0219	4276	0.0159	5896	0.0220	4294	0.0160	5938	0.0221
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4124	0.0154	5638	0.0210	4077	0.0152	5555	0.0207	4032	0.0150	5485	0.0204	3999	0.0149	5436	0.0202
2	4131	0.0154	5650	0.0210	4087	0.0152	5571	0.0207	4044	0.0151	5505	0.0205	4014	0.0149	5462	0.0203
3	4138	0.0154	5663	0.0211	4095	0.0152	5587	0.0208	4057	0.0151	5526	0.0206	4029	0.0150	5487	0.0204
4	4145	0.0154	5675	0.0211	4105	0.0153	5603	0.0209	4069	0.0151	5547	0.0207	4045	0.0151	5513	0.0205
5	4152	0.0155	5688	0.0212	4114	0.0153	5618	0.0209	4082	0.0152	5569	0.0207	4061	0.0151	5540	0.0206
6	4159	0.0155	5701	0.0212	4123	0.0153	5634	0.0210	4094	0.0152	5590	0.0208	4076	0.0152	5566	0.0207
7	4167	0.0155	5714	0.0213	4132	0.0154	5650	0.0210	4106	0.0153	5611	0.0209	4092	0.0152	5593	0.0208
8	4174	0.0155	5726	0.0213	4141	0.0154	5666	0.0211	4119	0.0153	5632	0.0210	4108	0.0153	5619	0.0209
9	4182	0.0156	5739	0.0214	4150	0.0155	5682	0.0212	4131	0.0154	5653	0.0210	4123	0.0154	5646	0.0210
10	4189	0.0156	5752	0.0214	4160	0.0155	5699	0.0212	4144	0.0154	5675	0.0211	4139	0.0154	5673	0.0211
11	4196	0.0156	5765	0.0215	4169	0.0155	5715	0.0213	4156	0.0155	5697	0.0212	4154	0.0155	5700	0.0212
12	4204	0.0157	5778	0.0215	4179	0.0156	5732	0.0213	4169	0.0155	5719	0.0213	4170	0.0155	5728	0.0213
13	4211	0.0157	5791	0.0216	4188	0.0156	5748	0.0214	4181	0.0156	5741	0.0214	4186	0.0156	5756	0.0214
14	4219	0.0157	5804	0.0216	4198	0.0156	5765	0.0215	4194	0.0156	5764	0.0215	4202	0.0156	5784	0.0215
15	4226	0.0157	5817	0.0217	4208	0.0157	5782	0.0215	4207	0.0157	5787	0.0215	4218	0.0157	5812	0.0216
16	4234	0.0158	5830	0.0217	4217	0.0157	5799	0.0216	4221	0.0157	5810	0.0216	4235	0.0158	5841	0.0217
17	4242	0.0158	5844	0.0218	4227	0.0157	5816	0.0217	4234	0.0158	5832	0.0217	4251	0.0158	5870	0.0219
18	4249	0.0158	5857	0.0218	4237	0.0158	5834	0.0217	4247	0.0158	5856	0.0218	4268	0.0159	5900	0.0220
19	4257	0.0158	5871	0.0219	4247	0.0158	5851	0.0218	4260	0.0159	5880	0.0219	4284	0.0160	5928	0.0221
20	4265	0.0159	5884	0.0219	4257	0.0158	5869	0.0218	4273	0.0159	5902	0.0220	4299	0.0160	5955	0.0222
21	4272	0.0159	5897	0.0220	4266	0.0159	5884	0.0219	4285	0.0160	5923	0.0221	4315	0.0161	5982	0.0223
22	4278	0.0159	5909	0.0220	4275	0.0159	5900	0.0220	4297	0.0160	5945	0.0221	4330	0.0161	6010	0.0224
23	4285	0.0160	5921	0.0220	4284	0.0159	5916	0.0220	4309	0.0160	5966	0.0222	4345	0.0162	6037	0.0225
24	4292	0.0160	5933	0.0221	4293	0.0160	5932	0.0221	4321	0.0161	5988	0.0223	4361	0.0162	6065	0.0226
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3958	0.0147	5373	0.0200	3907	0.0145	5279	0.0197	3885	0.0145	5242	0.0195	3861	0.0144	5192	0.0193
2	3976	0.0148	5403	0.0201	3932	0.0146	5324	0.0198	3910	0.0146	5287	0.0197	3887	0.0145	5239	0.0195
3	3994	0.0149	5433	0.0202	3950	0.0147	5355	0.0199	3936	0.0147	5335	0.0199	3913	0.0146	5286	0.0197
4	4012	0.0149	5463	0.0203	3969	0.0148	5386	0.0201	3955	0.0147	5367	0.0200	3935	0.0146	5323	0.0198
5	4030	0.0150	5494	0.0205	3988	0.0148	5418	0.0202	3975	0.0148	5399	0.0201	3954	0.0147	5356	0.0199
6	4049	0.0151	5525	0.0206	4007	0.0149	5450	0.0203	3994	0.0149	5432	0.0202	3974	0.0148	5389	0.0201
7	4068	0.0151	5557	0.0207	4027	0.0150	5483	0.0204	4014	0.0149	5465	0.0203	3993	0.0149	5422	0.0202
8	4087	0.0152	5589	0.0208	4046	0.0151	5516	0.0205	4034	0.0150	5498	0.0205	4014	0.0149	5456	0.0203
9	4106	0.0153	5621	0.0209	4066	0.0151	5549	0.0207	4054	0.0151	5533	0.0206	4034	0.0150	5490	0.0204
10	4124	0.0154	5653	0.0210	4086	0.0152	5583	0.0208	4074	0.0152	5567	0.0207	4054	0.0151	5524	0.0206
11	4143	0.0154	5686	0.0212	4106	0.0153	5617	0.0209	4095	0.0152	5602	0.0209	4076	0.0152	5559	0.0207
12	4162	0.0155	5718	0.0213	4126	0.0154	5651	0.0210	4116	0.0153	5637	0.0210	4096	0.0153	5595	0.0208
13	4181	0.0156	5752	0.0214	4146	0.0154	5686	0.0212	4136	0.0154	5672	0.0211	4117	0.0153	5630	0.0210
14	4200	0.0156	5786	0.0215	4166	0.0155	5721	0.0213	4156	0.0155	5707	0.0212	4137	0.0154	5665	

Table H11: Heat transfer coefficients and Biot number approximations for R3-60 at 7LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3791	0.0141	4823	0.0180	3793	0.0141	4830	0.0180	3793	0.0141	4836	0.0180	3788	0.0141	4830	0.0180
2	3791	0.0141	4824	0.0180	3794	0.0141	4831	0.0180	3794	0.0141	4838	0.0180	3790	0.0141	4833	0.0180
3	3792	0.0141	4825	0.0180	3795	0.0141	4832	0.0180	3796	0.0141	4841	0.0180	3792	0.0141	4836	0.0180
4	3792	0.0141	4826	0.0180	3795	0.0141	4833	0.0180	3797	0.0141	4843	0.0180	3793	0.0141	4839	0.0180
5	3793	0.0141	4827	0.0180	3796	0.0141	4834	0.0180	3799	0.0141	4845	0.0180	3795	0.0141	4842	0.0180
6	3793	0.0141	4828	0.0180	3797	0.0141	4835	0.0180	3800	0.0141	4847	0.0180	3797	0.0141	4845	0.0180
7	3794	0.0141	4829	0.0180	3797	0.0141	4836	0.0180	3801	0.0142	4849	0.0181	3798	0.0141	4847	0.0180
8	3794	0.0141	4829	0.0180	3798	0.0141	4837	0.0180	3802	0.0142	4851	0.0181	3800	0.0141	4851	0.0181
9	3795	0.0141	4830	0.0180	3798	0.0141	4838	0.0180	3803	0.0142	4852	0.0181	3802	0.0142	4853	0.0181
10	3796	0.0141	4831	0.0180	3799	0.0141	4839	0.0180	3804	0.0142	4854	0.0181	3804	0.0142	4856	0.0181
11	3796	0.0141	4832	0.0180	3800	0.0141	4840	0.0180	3805	0.0142	4856	0.0181	3805	0.0142	4859	0.0181
12	3797	0.0141	4833	0.0180	3800	0.0141	4841	0.0180	3807	0.0142	4858	0.0181	3807	0.0142	4861	0.0181
13	3797	0.0141	4833	0.0180	3801	0.0142	4843	0.0180	3808	0.0142	4860	0.0181	3809	0.0142	4864	0.0181
14	3798	0.0141	4834	0.0180	3802	0.0142	4844	0.0180	3809	0.0142	4862	0.0181	3810	0.0142	4866	0.0181
15	3798	0.0141	4835	0.0180	3802	0.0142	4845	0.0180	3810	0.0142	4864	0.0181	3812	0.0142	4869	0.0181
16	3799	0.0141	4836	0.0180	3803	0.0142	4846	0.0180	3811	0.0142	4866	0.0181	3813	0.0142	4871	0.0181
17	3799	0.0141	4837	0.0180	3803	0.0142	4846	0.0180	3813	0.0142	4868	0.0181	3814	0.0142	4874	0.0181
18	3800	0.0141	4838	0.0180	3804	0.0142	4847	0.0180	3814	0.0142	4870	0.0181	3816	0.0142	4877	0.0182
19	3800	0.0141	4839	0.0180	3805	0.0142	4848	0.0181	3815	0.0142	4871	0.0181	3818	0.0142	4879	0.0182
20	3801	0.0142	4840	0.0180	3805	0.0142	4849	0.0181	3816	0.0142	4873	0.0181	3819	0.0142	4882	0.0182
21	3802	0.0142	4841	0.0180	3806	0.0142	4851	0.0181	3817	0.0142	4875	0.0182	3821	0.0142	4884	0.0182
22	3802	0.0142	4842	0.0180	3807	0.0142	4852	0.0181	3818	0.0142	4877	0.0182	3822	0.0142	4886	0.0182
23	3802	0.0142	4842	0.0180	3807	0.0142	4853	0.0181	3819	0.0142	4879	0.0182	3824	0.0142	4889	0.0182
24	3803	0.0142	4843	0.0180	3808	0.0142	4854	0.0181	3821	0.0142	4881	0.0182	3826	0.0142	4892	0.0182
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3766	0.0140	4809	0.0179	3744	0.0139	4775	0.0178	3650	0.0136	4612	0.0172	3621	0.0135	4573	0.0170
2	3769	0.0140	4814	0.0179	3749	0.0140	4783	0.0178	3658	0.0136	4624	0.0172	3632	0.0135	4590	0.0171
3	3773	0.0140	4821	0.0179	3754	0.0140	4790	0.0178	3666	0.0136	4637	0.0173	3643	0.0136	4607	0.0172
4	3777	0.0141	4827	0.0180	3758	0.0140	4798	0.0179	3674	0.0137	4650	0.0173	3654	0.0136	4624	0.0172
5	3781	0.0141	4833	0.0180	3763	0.0140	4806	0.0179	3682	0.0137	4663	0.0174	3665	0.0136	4640	0.0173
6	3784	0.0141	4839	0.0180	3768	0.0140	4814	0.0179	3690	0.0137	4676	0.0174	3675	0.0137	4657	0.0173
7	3788	0.0141	4846	0.0180	3773	0.0140	4822	0.0180	3698	0.0138	4689	0.0175	3686	0.0137	4674	0.0174
8	3792	0.0141	4852	0.0181	3777	0.0141	4829	0.0180	3706	0.0138	4702	0.0175	3696	0.0138	4691	0.0175
9	3796	0.0141	4858	0.0181	3782	0.0141	4837	0.0180	3714	0.0138	4715	0.0176	3707	0.0138	4708	0.0175
10	3800	0.0141	4865	0.0181	3787	0.0141	4845	0.0180	3723	0.0139	4729	0.0176	3717	0.0138	4726	0.0176
11	3804	0.0142	4871	0.0181	3792	0.0141	4853	0.0181	3731	0.0139	4742	0.0177	3729	0.0139	4743	0.0177
12	3808	0.0142	4877	0.0182	3797	0.0141	4862	0.0181	3739	0.0139	4756	0.0177	3739	0.0139	4761	0.0177
13	3812	0.0142	4884	0.0182	3802	0.0142	4869	0.0181	3748	0.0140	4769	0.0178	3750	0.0140	4779	0.0178
14	3816	0.0142	4890	0.0182	3807	0.0142	4877	0.0182	3756	0.0140	4783	0.0178	3761	0.0140	4797	0.0179
15	3819	0.0142	4896	0.0182	3812	0.0142	4885	0.0182	3765	0.0140	4796	0.0179	3773	0.0140	4815	0.0179
16	3823	0.0142	4903	0.0183	3817	0.0142	4894	0.0182	3773	0.0140	4810	0.0179	3784	0.0141	4833	0.0180
17	3828	0.0143	4910	0.0183	3822	0.0142	4902	0.0182	3782	0.0141	4824	0.0180	3795	0.0141	4852	0.0181
18	3831	0.0143	4916	0.0183	3827	0.0142	4910	0.0183	3790	0.0141	4838	0.0180	3807	0.0142	4870	0.0181
19	3835	0.0143	4922	0.0183	3832	0.0143	4918	0.0183	3799	0.0141	4853	0.0181	3818	0.0142	4889	0.0182
20	3839	0.0143	4928	0.0183	3837	0.0143	4926	0.0183	3808	0.0142	4867	0.0181	3829	0.0143	4907	0.0183
21	3842	0.0143	4933	0.0184	3841	0.0143	4933	0.0184	3816	0.0142	4881	0.0182	3839	0.0143	4923	0.0183
22	3846	0.0143	4939	0.0184	3846	0.0143	4941	0.0184	3824	0.0142	4893	0.0182	3849	0.0143	4940	0.0184
23	3849	0.0143	4945	0.0184	3850	0.0143	4948	0.0184	3832	0.0143	4906	0.0183	3860	0.0144	4958	0.0185
24	3852	0.0143	4951	0.0184	3854	0.0144	4955	0.0184	3840	0.0143	4919	0.0183	3870	0.0144	4975	0.0185
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3584	0.0133	4528	0.0169	3527	0.0131	4433	0.0165	3489	0.0130	4368	0.0163	3475	0.0129	4344	0.0162
2	3599	0.0134	4552	0.0169	3545	0.0132	4460	0.0166	3513	0.0131	4409	0.0164	3500	0.0130	4386	0.0163
3	3614	0.0135	4576	0.0170	3562	0.0133	4487	0.0167	3533	0.0132	4442	0.0165	3523	0.0131	4424	0.0165
4	3630	0.0135	4600	0.0171	3580	0.0133	4515	0.0168	3552	0.0132	4470	0.0166	3542	0.0132	4453	0.0166
5	3646	0.0136	4625	0.0172	3598	0.0134	4543	0.0169	3570	0.0133	4499	0.0167	3560	0.0133	4482	0.0167
6	3661	0.0136	4649	0.0173	3616	0.0135	4571	0.0170	3589	0.0134	4528	0.0169	3580	0.0133	4512	0.0168
7	3677	0.0137	4674	0.0174	3634	0.0135	4600	0.0171	3608	0.0134	4558	0.0170	3599	0.0134	4542	0.0169
8	3693	0.0138	4700	0.0175	3653	0.0136	4629	0.0172	3627	0.0135	4588	0.0171	3619	0.0135	4573	0.0170
9	3709	0.0138	4725	0.0176	3672	0.0137	4659	0.0173	3647	0.0136	4619	0.0172	3639	0.0135	4604	0.0171
10	3724	0.0139	4750	0.0177	3690	0.0137	4688	0.0175	3667	0.0137	4649	0.0173	3659	0.0136	4636	0.0173
11	3740	0.0139	4776	0.0178	3709	0.0138	4718	0.0176	3686	0.0137	4681	0.0174	3679	0.0137	4667	0.0174
12	3756	0.0140	4802	0.0179	3727	0.0139	4748	0.0177	3705	0.0138	4711	0.0175	3699	0.0138	4699	0.0175
13	3772	0.0140	4828	0.0180	3746	0.0139	4778	0.0178	3725	0.0139	4743	0.0177	3718	0.0138	4731	0.0176
14	3789	0.0141	4854	0.0181	3765	0.0140	4809	0.0179	3745	0.0139	4775	0.0178	3739	0.0139	4764	

Table H12: Heat transfer coefficients and Biot number approximations for R3-60 at 5.5LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3283	0.0122	3801	0.0142	3275	0.0122	3788	0.0141	3271	0.0122	3784	0.0141	3252	0.0121	3754	0.0140
2	3283	0.0122	3801	0.0142	3276	0.0122	3789	0.0141	3272	0.0122	3786	0.0141	3254	0.0121	3757	0.0140
3	3284	0.0122	3802	0.0142	3277	0.0122	3790	0.0141	3273	0.0122	3788	0.0141	3255	0.0121	3759	0.0140
4	3284	0.0122	3803	0.0142	3277	0.0122	3791	0.0141	3274	0.0122	3789	0.0141	3257	0.0121	3762	0.0140
5	3284	0.0122	3803	0.0142	3278	0.0122	3792	0.0141	3275	0.0122	3791	0.0141	3259	0.0121	3764	0.0140
6	3285	0.0122	3804	0.0142	3278	0.0122	3793	0.0141	3276	0.0122	3792	0.0141	3260	0.0121	3767	0.0140
7	3285	0.0122	3805	0.0142	3279	0.0122	3794	0.0141	3277	0.0122	3794	0.0141	3262	0.0121	3769	0.0140
8	3286	0.0122	3806	0.0142	3280	0.0122	3795	0.0141	3278	0.0122	3796	0.0141	3263	0.0121	3771	0.0140
9	3286	0.0122	3806	0.0142	3280	0.0122	3796	0.0141	3279	0.0122	3797	0.0141	3265	0.0122	3774	0.0140
10	3287	0.0122	3807	0.0142	3281	0.0122	3797	0.0141	3280	0.0122	3799	0.0141	3267	0.0122	3776	0.0141
11	3287	0.0122	3808	0.0142	3282	0.0122	3798	0.0141	3281	0.0122	3800	0.0141	3268	0.0122	3778	0.0141
12	3288	0.0122	3808	0.0142	3282	0.0122	3799	0.0141	3283	0.0122	3802	0.0142	3270	0.0122	3781	0.0141
13	3288	0.0122	3809	0.0142	3283	0.0122	3800	0.0141	3284	0.0122	3804	0.0142	3272	0.0122	3783	0.0141
14	3289	0.0122	3809	0.0142	3284	0.0122	3801	0.0141	3285	0.0122	3805	0.0142	3273	0.0122	3786	0.0141
15	3289	0.0122	3810	0.0142	3284	0.0122	3802	0.0142	3286	0.0122	3807	0.0142	3275	0.0122	3788	0.0141
16	3290	0.0122	3811	0.0142	3285	0.0122	3803	0.0142	3287	0.0122	3808	0.0142	3277	0.0122	3790	0.0141
17	3290	0.0122	3812	0.0142	3286	0.0122	3804	0.0142	3288	0.0122	3810	0.0142	3278	0.0122	3793	0.0141
18	3291	0.0123	3812	0.0142	3286	0.0122	3804	0.0142	3289	0.0123	3812	0.0142	3280	0.0122	3796	0.0141
19	3291	0.0123	3813	0.0142	3287	0.0122	3806	0.0142	3290	0.0123	3814	0.0142	3281	0.0122	3798	0.0141
20	3291	0.0123	3814	0.0142	3288	0.0122	3807	0.0142	3292	0.0123	3815	0.0142	3283	0.0122	3800	0.0141
21	3292	0.0123	3815	0.0142	3288	0.0122	3807	0.0142	3293	0.0123	3817	0.0142	3285	0.0122	3803	0.0142
22	3292	0.0123	3815	0.0142	3289	0.0122	3808	0.0142	3294	0.0123	3818	0.0142	3287	0.0122	3805	0.0142
23	3293	0.0123	3816	0.0142	3290	0.0122	3810	0.0142	3295	0.0123	3820	0.0142	3288	0.0122	3807	0.0142
24	3293	0.0123	3816	0.0142	3290	0.0122	3810	0.0142	3296	0.0123	3822	0.0142	3290	0.0122	3810	0.0142
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3240	0.0121	3742	0.0139	3223	0.0120	3717	0.0138	3212	0.0120	3713	0.0138	3185	0.0119	3679	0.0137
2	3243	0.0121	3746	0.0139	3226	0.0120	3722	0.0139	3217	0.0120	3720	0.0139	3193	0.0119	3691	0.0137
3	3245	0.0121	3750	0.0140	3230	0.0120	3727	0.0139	3222	0.0120	3728	0.0139	3201	0.0119	3702	0.0138
4	3248	0.0121	3754	0.0140	3233	0.0120	3732	0.0139	3228	0.0120	3736	0.0139	3210	0.0120	3714	0.0138
5	3251	0.0121	3758	0.0140	3236	0.0120	3737	0.0139	3233	0.0120	3744	0.0139	3218	0.0120	3726	0.0139
6	3253	0.0121	3762	0.0140	3240	0.0121	3742	0.0139	3238	0.0121	3752	0.0140	3226	0.0120	3738	0.0139
7	3256	0.0121	3765	0.0140	3243	0.0121	3747	0.0140	3244	0.0121	3760	0.0140	3233	0.0120	3749	0.0140
8	3259	0.0121	3770	0.0140	3247	0.0121	3752	0.0140	3249	0.0121	3768	0.0140	3242	0.0121	3761	0.0140
9	3261	0.0121	3773	0.0140	3250	0.0121	3757	0.0140	3254	0.0121	3776	0.0141	3249	0.0121	3773	0.0140
10	3264	0.0122	3777	0.0141	3253	0.0121	3762	0.0140	3260	0.0121	3784	0.0141	3257	0.0121	3785	0.0141
11	3267	0.0122	3781	0.0141	3257	0.0121	3767	0.0140	3265	0.0122	3792	0.0141	3266	0.0122	3797	0.0141
12	3269	0.0122	3785	0.0141	3260	0.0121	3772	0.0140	3271	0.0122	3800	0.0141	3274	0.0122	3809	0.0142
13	3272	0.0122	3789	0.0141	3264	0.0122	3777	0.0141	3276	0.0122	3808	0.0142	3282	0.0122	3821	0.0142
14	3275	0.0122	3793	0.0141	3267	0.0122	3782	0.0141	3282	0.0122	3817	0.0142	3290	0.0123	3833	0.0143
15	3277	0.0122	3797	0.0141	3271	0.0122	3788	0.0141	3287	0.0122	3825	0.0142	3299	0.0123	3846	0.0143
16	3280	0.0122	3801	0.0142	3274	0.0122	3793	0.0141	3293	0.0123	3833	0.0143	3307	0.0123	3858	0.0144
17	3283	0.0122	3805	0.0142	3278	0.0122	3798	0.0141	3299	0.0123	3842	0.0143	3316	0.0123	3871	0.0144
18	3285	0.0122	3809	0.0142	3281	0.0122	3803	0.0142	3304	0.0123	3850	0.0143	3324	0.0124	3884	0.0145
19	3288	0.0122	3813	0.0142	3285	0.0122	3808	0.0142	3310	0.0123	3858	0.0144	3333	0.0124	3896	0.0145
20	3291	0.0123	3817	0.0142	3288	0.0122	3813	0.0142	3316	0.0123	3867	0.0144	3342	0.0124	3909	0.0146
21	3293	0.0123	3821	0.0142	3292	0.0123	3818	0.0142	3321	0.0124	3875	0.0144	3350	0.0125	3922	0.0146
22	3296	0.0123	3825	0.0142	3295	0.0123	3824	0.0142	3327	0.0124	3884	0.0145	3358	0.0125	3934	0.0146
23	3299	0.0123	3829	0.0143	3299	0.0123	3829	0.0143	3333	0.0124	3892	0.0145	3366	0.0125	3945	0.0147
24	3302	0.0123	3833	0.0143	3302	0.0123	3834	0.0143	3339	0.0124	3901	0.0145	3374	0.0126	3957	0.0147
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3147	0.0117	3624	0.0135	3141	0.0117	3637	0.0135	3140	0.0117	3652	0.0136	3108	0.0116	3594	0.0134
2	3158	0.0118	3641	0.0136	3157	0.0118	3659	0.0136	3159	0.0118	3681	0.0137	3131	0.0117	3630	0.0135
3	3170	0.0118	3658	0.0136	3172	0.0118	3681	0.0137	3176	0.0118	3705	0.0138	3149	0.0117	3655	0.0136
4	3182	0.0118	3674	0.0137	3188	0.0119	3704	0.0138	3194	0.0119	3730	0.0139	3166	0.0118	3681	0.0137
5	3194	0.0119	3691	0.0137	3204	0.0119	3726	0.0139	3211	0.0120	3755	0.0140	3184	0.0119	3706	0.0138
6	3206	0.0119	3709	0.0138	3220	0.0120	3749	0.0140	3229	0.0120	3781	0.0141	3202	0.0119	3732	0.0139
7	3218	0.0120	3726	0.0139	3236	0.0120	3773	0.0140	3247	0.0121	3807	0.0142	3220	0.0120	3759	0.0140
8	3229	0.0120	3743	0.0139	3253	0.0121	3796	0.0141	3265	0.0122	3833	0.0143	3239	0.0121	3786	0.0141
9	3241	0.0121	3760	0.0140	3269	0.0122	3820	0.0142	3284	0.0122	3860	0.0144	3258	0.0121	3813	0.0142
10	3253	0.0121	3778	0.0141	3285	0.0122	3844	0.0143	3302	0.0123	3887	0.0145	3277	0.0122	3840	0.0143
11	3265	0.0122	3795	0.0141	3301	0.0123	3868	0.0144	3320	0.0124	3914	0.0146	3295	0.0123	3868	0.0144
12	3277	0.0122	3813	0.0142	3317	0.0124	3893	0.0145	3338	0.0124	3941	0.0147	3314	0.0123	3896	0.0145
13	3289	0.0122	3831	0.0143	3334	0.0124	3917	0.0146	3356	0.0125	3969	0.0148	3333	0.0124	3924	0.0146
14	3301	0.0123	3849	0.0143	3351	0.0125	3943	0.0147	3375	0.0126	3997	0.0149	3352	0.0125	3953	

Table H13: Heat transfer coefficients and Biot number approximations for R4-36 at 14LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3798	0.0154	5354	0.0217	4296	0.0174	6588	0.0267	4560	0.0185	7283	0.0295	4553	0.0185	7290	0.0296
2	3798	0.0154	5355	0.0217	4296	0.0174	6588	0.0267	4560	0.0185	7283	0.0295	4556	0.0185	7296	0.0296
3	3798	0.0154	5355	0.0217	4296	0.0174	6588	0.0267	4560	0.0185	7283	0.0295	4559	0.0185	7302	0.0296
4	3798	0.0154	5355	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4562	0.0185	7309	0.0296
5	3798	0.0154	5355	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4566	0.0185	7315	0.0297
6	3798	0.0154	5355	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4569	0.0185	7322	0.0297
7	3798	0.0154	5356	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4572	0.0185	7328	0.0297
8	3798	0.0154	5356	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4575	0.0186	7334	0.0297
9	3799	0.0154	5356	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4578	0.0186	7341	0.0298
10	3799	0.0154	5356	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4581	0.0186	7347	0.0298
11	3799	0.0154	5356	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4584	0.0186	7353	0.0298
12	3799	0.0154	5357	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4587	0.0186	7359	0.0298
13	3799	0.0154	5357	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4589	0.0186	7364	0.0299
14	3799	0.0154	5357	0.0217	4297	0.0174	6589	0.0267	4561	0.0185	7284	0.0295	4592	0.0186	7370	0.0299
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4470	0.0181	7127	0.0289	4429	0.0180	7052	0.0286	4308	0.0175	6812	0.0276	4265	0.0173	6732	0.0273
2	4479	0.0182	7146	0.0290	4442	0.0180	7078	0.0287	4328	0.0176	6851	0.0278	4286	0.0174	6774	0.0275
3	4489	0.0182	7165	0.0291	4455	0.0181	7105	0.0288	4349	0.0176	6891	0.0279	4308	0.0175	6816	0.0276
4	4499	0.0182	7185	0.0291	4469	0.0181	7132	0.0289	4369	0.0177	6931	0.0281	4330	0.0176	6859	0.0278
5	4508	0.0183	7204	0.0292	4482	0.0182	7160	0.0290	4390	0.0178	6972	0.0283	4352	0.0176	6902	0.0280
6	4518	0.0183	7224	0.0293	4496	0.0182	7188	0.0291	4411	0.0179	7013	0.0284	4374	0.0177	6946	0.0282
7	4528	0.0184	7244	0.0294	4509	0.0183	7215	0.0293	4431	0.0180	7054	0.0286	4397	0.0178	6991	0.0283
8	4538	0.0184	7264	0.0295	4523	0.0183	7244	0.0294	4452	0.0181	7096	0.0288	4420	0.0179	7036	0.0285
9	4548	0.0184	7284	0.0295	4537	0.0184	7272	0.0295	4473	0.0181	7138	0.0289	4442	0.0180	7080	0.0287
10	4557	0.0185	7305	0.0296	4551	0.0185	7301	0.0296	4494	0.0182	7181	0.0291	4464	0.0181	7126	0.0289
11	4567	0.0185	7325	0.0297	4566	0.0185	7330	0.0297	4515	0.0183	7224	0.0293	4487	0.0182	7172	0.0291
12	4578	0.0186	7346	0.0298	4580	0.0186	7359	0.0298	4537	0.0184	7268	0.0295	4510	0.0183	7218	0.0293
13	4588	0.0186	7367	0.0299	4594	0.0186	7388	0.0300	4559	0.0185	7312	0.0297	4533	0.0184	7266	0.0295
14	4597	0.0186	7385	0.0299	4608	0.0187	7416	0.0301	4581	0.0186	7357	0.0298	4557	0.0185	7314	0.0297
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4260	0.0173	6750	0.0274	4238	0.0172	6715	0.0272	4173	0.0169	6552	0.0266	4162	0.0169	6524	0.0265
2	4284	0.0174	6800	0.0276	4266	0.0173	6774	0.0275	4201	0.0170	6611	0.0268	4190	0.0170	6583	0.0267
3	4305	0.0175	6841	0.0277	4294	0.0174	6833	0.0277	4230	0.0172	6672	0.0271	4219	0.0171	6644	0.0269
4	4327	0.0175	6885	0.0279	4315	0.0175	6874	0.0279	4254	0.0173	6721	0.0273	4244	0.0172	6696	0.0272
5	4350	0.0176	6928	0.0281	4336	0.0176	6915	0.0280	4276	0.0173	6762	0.0274	4266	0.0173	6738	0.0273
6	4372	0.0177	6973	0.0283	4357	0.0177	6958	0.0282	4297	0.0174	6804	0.0276	4288	0.0174	6781	0.0275
7	4395	0.0178	7017	0.0285	4379	0.0178	7001	0.0284	4319	0.0175	6847	0.0278	4310	0.0175	6824	0.0277
8	4418	0.0179	7062	0.0286	4401	0.0178	7043	0.0286	4341	0.0176	6891	0.0279	4332	0.0176	6866	0.0278
9	4441	0.0180	7108	0.0288	4423	0.0179	7087	0.0287	4363	0.0177	6934	0.0281	4354	0.0177	6911	0.0280
10	4464	0.0181	7155	0.0290	4445	0.0180	7132	0.0289	4386	0.0178	6978	0.0283	4377	0.0177	6955	0.0282
11	4487	0.0182	7201	0.0292	4468	0.0181	7177	0.0291	4409	0.0179	7023	0.0285	4400	0.0178	7001	0.0284
12	4510	0.0183	7248	0.0294	4491	0.0182	7222	0.0293	4432	0.0180	7068	0.0287	4423	0.0179	7047	0.0286
13	4533	0.0184	7295	0.0296	4513	0.0183	7267	0.0295	4454	0.0181	7114	0.0288	4446	0.0180	7092	0.0288
14	4557	0.0185	7344	0.0298	4535	0.0184	7313	0.0297	4477	0.0182	7160	0.0290	4469	0.0181	7138	0.0289

Table H14: Heat transfer coefficients and Biot number approximations for R4-36 at 12LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4277	0.0173	6536	0.0265	4261	0.0173	6511	0.0264	4241	0.0172	6473	0.0262	4170	0.0169	6333	0.0257
2	4278	0.0173	6537	0.0265	4264	0.0173	6516	0.0264	4245	0.0172	6480	0.0263	4178	0.0169	6350	0.0257
3	4278	0.0173	6538	0.0265	4266	0.0173	6521	0.0264	4249	0.0172	6488	0.0263	4187	0.0170	6367	0.0258
4	4279	0.0173	6539	0.0265	4269	0.0173	6526	0.0265	4253	0.0172	6496	0.0263	4196	0.0170	6384	0.0259
5	4279	0.0174	6540	0.0265	4271	0.0173	6529	0.0265	4257	0.0173	6504	0.0264	4205	0.0171	6402	0.0260
6	4279	0.0174	6541	0.0265	4273	0.0173	6534	0.0265	4261	0.0173	6512	0.0264	4214	0.0171	6419	0.0260
7	4280	0.0174	6542	0.0265	4275	0.0173	6538	0.0265	4265	0.0173	6520	0.0264	4223	0.0171	6436	0.0261
8	4280	0.0174	6543	0.0265	4278	0.0173	6543	0.0265	4270	0.0173	6528	0.0265	4232	0.0172	6454	0.0262
9	4281	0.0174	6544	0.0265	4280	0.0174	6546	0.0265	4273	0.0173	6535	0.0265	4241	0.0172	6472	0.0262
10	4281	0.0174	6545	0.0265	4282	0.0174	6551	0.0266	4277	0.0173	6542	0.0265	4251	0.0172	6490	0.0263
11	4282	0.0174	6545	0.0265	4284	0.0174	6555	0.0266	4280	0.0174	6549	0.0266	4260	0.0173	6508	0.0264
12	4282	0.0174	6547	0.0265	4286	0.0174	6560	0.0266	4284	0.0174	6556	0.0266	4269	0.0173	6526	0.0265
13	4283	0.0174	6547	0.0265	4288	0.0174	6564	0.0266	4288	0.0174	6563	0.0266	4277	0.0173	6542	0.0265
14	4283	0.0174	6549	0.0266	4291	0.0174	6568	0.0266	4291	0.0174	6570	0.0266	4285	0.0174	6558	0.0266
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	4096	0.0166	6193	0.0251	4086	0.0166	6188	0.0251	4034	0.0164	6092	0.0247	4002	0.0162	6042	0.0245
2	4110	0.0167	6220	0.0252	4103	0.0166	6219	0.0252	4054	0.0164	6129	0.0249	4023	0.0163	6082	0.0247
3	4124	0.0167	6247	0.0253	4120	0.0167	6251	0.0253	4074	0.0165	6166	0.0250	4045	0.0164	6122	0.0248
4	4139	0.0168	6275	0.0254	4136	0.0168	6283	0.0255	4094	0.0166	6205	0.0252	4067	0.0165	6163	0.0250
5	4153	0.0168	6303	0.0256	4153	0.0168	6314	0.0256	4115	0.0167	6243	0.0253	4089	0.0166	6204	0.0252
6	4168	0.0169	6331	0.0257	4170	0.0169	6347	0.0257	4134	0.0168	6280	0.0255	4111	0.0167	6246	0.0253
7	4183	0.0170	6359	0.0258	4187	0.0170	6380	0.0259	4154	0.0168	6319	0.0256	4133	0.0168	6288	0.0255
8	4197	0.0170	6388	0.0259	4203	0.0170	6412	0.0260	4174	0.0169	6358	0.0258	4155	0.0168	6330	0.0257
9	4212	0.0171	6417	0.0260	4221	0.0171	6446	0.0261	4195	0.0170	6398	0.0259	4177	0.0169	6373	0.0258
10	4227	0.0171	6446	0.0261	4238	0.0172	6480	0.0263	4216	0.0171	6438	0.0261	4200	0.0170	6416	0.0260
11	4243	0.0172	6475	0.0263	4256	0.0173	6514	0.0264	4236	0.0172	6478	0.0263	4222	0.0171	6460	0.0262
12	4258	0.0173	6506	0.0264	4274	0.0173	6549	0.0266	4258	0.0173	6520	0.0264	4246	0.0172	6506	0.0264
13	4273	0.0173	6535	0.0265	4292	0.0174	6584	0.0267	4279	0.0174	6562	0.0266	4269	0.0173	6551	0.0266
14	4287	0.0174	6562	0.0266	4308	0.0175	6615	0.0268	4300	0.0174	6603	0.0268	4293	0.0174	6597	0.0268
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3952	0.0160	5940	0.0241	3926	0.0159	5893	0.0239	3906	0.0158	5851	0.0237	3916	0.0159	5879	0.0238
2	3973	0.0161	5979	0.0242	3953	0.0160	5948	0.0241	3934	0.0160	5908	0.0240	3944	0.0160	5935	0.0241
3	3995	0.0162	6019	0.0244	3974	0.0161	5986	0.0243	3959	0.0161	5955	0.0241	3970	0.0161	5987	0.0243
4	4016	0.0163	6059	0.0246	3995	0.0162	6025	0.0244	3980	0.0161	5994	0.0243	3991	0.0162	6027	0.0244
5	4038	0.0164	6100	0.0247	4016	0.0163	6065	0.0246	4001	0.0162	6034	0.0245	4013	0.0163	6066	0.0246
6	4061	0.0165	6142	0.0249	4038	0.0164	6105	0.0248	4022	0.0163	6074	0.0246	4034	0.0164	6107	0.0248
7	4083	0.0166	6183	0.0251	4060	0.0165	6145	0.0249	4044	0.0164	6115	0.0248	4056	0.0164	6148	0.0249
8	4106	0.0166	6226	0.0252	4082	0.0166	6186	0.0251	4066	0.0165	6156	0.0250	4078	0.0165	6189	0.0251
9	4128	0.0167	6268	0.0254	4104	0.0166	6228	0.0253	4089	0.0166	6198	0.0251	4101	0.0166	6231	0.0253
10	4150	0.0168	6312	0.0256	4126	0.0167	6270	0.0254	4112	0.0167	6240	0.0253	4124	0.0167	6274	0.0254
11	4173	0.0169	6355	0.0258	4148	0.0168	6312	0.0256	4134	0.0168	6283	0.0255	4146	0.0168	6317	0.0256
12	4196	0.0170	6399	0.0259	4170	0.0169	6355	0.0258	4156	0.0169	6325	0.0256	4168	0.0169	6360	0.0258
13	4219	0.0171	6444	0.0261	4193	0.0170	6398	0.0259	4178	0.0169	6369	0.0258	4191	0.0170	6403	0.0260
14	4243	0.0172	6490	0.0263	4215	0.0171	6442	0.0261	4201	0.0170	6413	0.0260	4214	0.0171	6448	0.0261

Table H15: Heat transfer coefficients and Biot number approximations for R4-36 at 10LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3880	0.0157	5549	0.0225	3887	0.0158	5566	0.0226	3898	0.0158	5593	0.0227	3884	0.0158	5577	0.0226
2	3880	0.0157	5549	0.0225	3887	0.0158	5566	0.0226	3898	0.0158	5593	0.0227	3887	0.0158	5582	0.0226
3	3880	0.0157	5549	0.0225	3887	0.0158	5566	0.0226	3898	0.0158	5593	0.0227	3890	0.0158	5587	0.0227
4	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3898	0.0158	5593	0.0227	3892	0.0158	5592	0.0227
5	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3898	0.0158	5593	0.0227	3895	0.0158	5596	0.0227
6	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3897	0.0158	5601	0.0227
7	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3900	0.0158	5606	0.0227
8	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3902	0.0158	5610	0.0227
9	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3904	0.0158	5614	0.0228
10	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3906	0.0158	5618	0.0228
11	3880	0.0157	5549	0.0225	3887	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3909	0.0158	5622	0.0228
12	3880	0.0157	5549	0.0225	3888	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3911	0.0159	5626	0.0228
13	3880	0.0157	5549	0.0225	3888	0.0158	5567	0.0226	3899	0.0158	5594	0.0227	3913	0.0159	5630	0.0228
14	3880	0.0157	5549	0.0225	3888	0.0158	5567	0.0226	3899	0.0158	5595	0.0227	3916	0.0159	5635	0.0228
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3826	0.0155	5478	0.0222	3797	0.0154	5427	0.0220	3748	0.0152	5355	0.0217	3710	0.0150	5294	0.0215
2	3834	0.0155	5493	0.0223	3807	0.0154	5445	0.0221	3764	0.0153	5383	0.0218	3729	0.0151	5328	0.0216
3	3841	0.0156	5507	0.0223	3817	0.0155	5463	0.0222	3780	0.0153	5411	0.0219	3748	0.0152	5361	0.0217
4	3849	0.0156	5520	0.0224	3827	0.0155	5481	0.0222	3795	0.0154	5439	0.0221	3767	0.0153	5395	0.0219
5	3857	0.0156	5534	0.0224	3837	0.0156	5499	0.0223	3810	0.0155	5466	0.0222	3787	0.0154	5430	0.0220
6	3865	0.0157	5549	0.0225	3847	0.0156	5518	0.0224	3826	0.0155	5495	0.0223	3806	0.0154	5464	0.0222
7	3872	0.0157	5563	0.0226	3857	0.0156	5536	0.0224	3842	0.0156	5524	0.0224	3824	0.0155	5498	0.0223
8	3880	0.0157	5577	0.0226	3867	0.0157	5555	0.0225	3857	0.0156	5552	0.0225	3844	0.0156	5534	0.0224
9	3888	0.0158	5592	0.0227	3877	0.0157	5573	0.0226	3873	0.0157	5582	0.0226	3863	0.0157	5569	0.0226
10	3896	0.0158	5607	0.0227	3888	0.0158	5593	0.0227	3890	0.0158	5612	0.0228	3883	0.0157	5606	0.0227
11	3904	0.0158	5621	0.0228	3898	0.0158	5611	0.0228	3906	0.0158	5642	0.0229	3903	0.0158	5642	0.0229
12	3912	0.0159	5636	0.0229	3909	0.0159	5631	0.0228	3923	0.0159	5672	0.0230	3924	0.0159	5680	0.0230
13	3919	0.0159	5649	0.0229	3919	0.0159	5649	0.0229	3939	0.0160	5703	0.0231	3944	0.0160	5718	0.0232
14	3927	0.0159	5663	0.0230	3928	0.0159	5667	0.0230	3955	0.0160	5731	0.0232	3963	0.0161	5754	0.0233
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3658	0.0148	5200	0.0211	3611	0.0146	5111	0.0207	3591	0.0146	5076	0.0206	3586	0.0145	5068	0.0206
2	3679	0.0149	5236	0.0212	3633	0.0147	5150	0.0209	3619	0.0147	5130	0.0208	3615	0.0147	5122	0.0208
3	3700	0.0150	5273	0.0214	3653	0.0148	5186	0.0210	3640	0.0148	5167	0.0210	3638	0.0148	5164	0.0209
4	3721	0.0151	5310	0.0215	3675	0.0149	5223	0.0212	3661	0.0148	5203	0.0211	3659	0.0148	5200	0.0211
5	3743	0.0152	5349	0.0217	3696	0.0150	5260	0.0213	3683	0.0149	5241	0.0213	3680	0.0149	5238	0.0212
6	3765	0.0153	5388	0.0218	3718	0.0151	5299	0.0215	3704	0.0150	5279	0.0214	3702	0.0150	5276	0.0214
7	3787	0.0154	5426	0.0220	3739	0.0152	5337	0.0216	3726	0.0151	5317	0.0216	3724	0.0151	5315	0.0216
8	3808	0.0154	5465	0.0222	3762	0.0153	5376	0.0218	3749	0.0152	5357	0.0217	3747	0.0152	5355	0.0217
9	3830	0.0155	5505	0.0223	3784	0.0153	5415	0.0220	3771	0.0153	5396	0.0219	3770	0.0153	5395	0.0219
10	3852	0.0156	5545	0.0225	3805	0.0154	5455	0.0221	3793	0.0154	5436	0.0220	3792	0.0154	5435	0.0220
11	3874	0.0157	5586	0.0227	3827	0.0155	5495	0.0223	3815	0.0155	5476	0.0222	3814	0.0155	5476	0.0222
12	3897	0.0158	5628	0.0228	3850	0.0156	5536	0.0224	3837	0.0156	5517	0.0224	3837	0.0156	5516	0.0224
13	3920	0.0159	5670	0.0230	3872	0.0157	5578	0.0226	3860	0.0157	5558	0.0225	3860	0.0157	5558	0.0225
14	3943	0.0160	5713	0.0232	3896	0.0158	5620	0.0228	3883	0.0157	5600	0.0227	3883	0.0157	5601	0.0227

Table H16: Heat transfer coefficients and Biot number approximations for R4-36 at 9LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3747	0.0152	5232	0.0212	3747	0.0152	5236	0.0212	3739	0.0152	5231	0.0212	3725	0.0151	5211	0.0211
2	3747	0.0152	5233	0.0212	3748	0.0152	5238	0.0212	3741	0.0152	5235	0.0212	3729	0.0151	5219	0.0212
3	3747	0.0152	5234	0.0212	3748	0.0152	5239	0.0212	3744	0.0152	5241	0.0213	3734	0.0151	5227	0.0212
4	3748	0.0152	5235	0.0212	3750	0.0152	5241	0.0213	3747	0.0152	5246	0.0213	3738	0.0152	5236	0.0212
5	3748	0.0152	5236	0.0212	3751	0.0152	5243	0.0213	3750	0.0152	5251	0.0213	3743	0.0152	5244	0.0213
6	3749	0.0152	5237	0.0212	3751	0.0152	5244	0.0213	3753	0.0152	5256	0.0213	3748	0.0152	5252	0.0213
7	3750	0.0152	5238	0.0212	3752	0.0152	5246	0.0213	3756	0.0152	5261	0.0213	3752	0.0152	5260	0.0213
8	3750	0.0152	5238	0.0212	3753	0.0152	5248	0.0213	3758	0.0152	5266	0.0214	3757	0.0152	5269	0.0214
9	3750	0.0152	5239	0.0212	3754	0.0152	5249	0.0213	3761	0.0153	5270	0.0214	3761	0.0153	5277	0.0214
10	3751	0.0152	5240	0.0212	3755	0.0152	5251	0.0213	3763	0.0153	5275	0.0214	3766	0.0153	5285	0.0214
11	3751	0.0152	5241	0.0213	3756	0.0152	5252	0.0213	3766	0.0153	5279	0.0214	3770	0.0153	5292	0.0215
12	3752	0.0152	5242	0.0213	3757	0.0152	5255	0.0213	3769	0.0153	5284	0.0214	3774	0.0153	5300	0.0215
13	3752	0.0152	5243	0.0213	3758	0.0152	5256	0.0213	3771	0.0153	5289	0.0214	3778	0.0153	5307	0.0215
14	3753	0.0152	5244	0.0213	3759	0.0152	5258	0.0213	3774	0.0153	5293	0.0215	3782	0.0153	5315	0.0216
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3677	0.0149	5131	0.0208	3651	0.0148	5084	0.0206	3594	0.0146	4997	0.0203	3549	0.0144	4913	0.0199
2	3686	0.0149	5146	0.0209	3660	0.0148	5102	0.0207	3610	0.0146	5024	0.0204	3566	0.0145	4943	0.0200
3	3694	0.0150	5161	0.0209	3671	0.0149	5120	0.0208	3626	0.0147	5051	0.0205	3584	0.0145	4973	0.0202
4	3702	0.0150	5176	0.0210	3681	0.0149	5138	0.0208	3642	0.0148	5078	0.0206	3602	0.0146	5004	0.0203
5	3711	0.0150	5191	0.0210	3691	0.0150	5156	0.0209	3657	0.0148	5105	0.0207	3620	0.0147	5034	0.0204
6	3719	0.0151	5206	0.0211	3702	0.0150	5175	0.0210	3673	0.0149	5133	0.0208	3637	0.0147	5065	0.0205
7	3728	0.0151	5221	0.0212	3712	0.0151	5193	0.0211	3688	0.0150	5161	0.0209	3655	0.0148	5096	0.0207
8	3736	0.0152	5237	0.0212	3722	0.0151	5212	0.0211	3704	0.0150	5189	0.0210	3673	0.0149	5128	0.0208
9	3745	0.0152	5252	0.0213	3733	0.0151	5231	0.0212	3720	0.0151	5218	0.0212	3691	0.0150	5160	0.0209
10	3753	0.0152	5267	0.0214	3744	0.0152	5250	0.0213	3737	0.0152	5247	0.0213	3709	0.0150	5192	0.0211
11	3762	0.0153	5283	0.0214	3754	0.0152	5269	0.0214	3753	0.0152	5276	0.0214	3727	0.0151	5225	0.0212
12	3771	0.0153	5299	0.0215	3765	0.0153	5288	0.0214	3770	0.0153	5306	0.0215	3746	0.0152	5259	0.0213
13	3779	0.0153	5313	0.0215	3776	0.0153	5307	0.0215	3786	0.0154	5336	0.0216	3765	0.0153	5292	0.0215
14	3787	0.0154	5327	0.0216	3785	0.0153	5324	0.0216	3802	0.0154	5364	0.0218	3784	0.0153	5326	0.0216
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3511	0.0142	4856	0.0197	3458	0.0140	4751	0.0193	3426	0.0139	4692	0.0190	3416	0.0139	4671	0.0189
2	3529	0.0143	4887	0.0198	3479	0.0141	4788	0.0194	3455	0.0140	4744	0.0192	3445	0.0140	4723	0.0192
3	3548	0.0144	4919	0.0199	3500	0.0142	4823	0.0196	3476	0.0141	4780	0.0194	3468	0.0141	4764	0.0193
4	3566	0.0145	4951	0.0201	3521	0.0143	4859	0.0197	3497	0.0142	4816	0.0195	3490	0.0142	4801	0.0195
5	3585	0.0145	4983	0.0202	3542	0.0144	4895	0.0198	3519	0.0143	4852	0.0197	3511	0.0142	4838	0.0196
6	3604	0.0146	5016	0.0203	3563	0.0144	4932	0.0200	3540	0.0144	4889	0.0198	3533	0.0143	4875	0.0198
7	3624	0.0147	5050	0.0205	3585	0.0145	4969	0.0201	3563	0.0144	4927	0.0200	3556	0.0144	4913	0.0199
8	3643	0.0148	5083	0.0206	3608	0.0146	5008	0.0203	3585	0.0145	4966	0.0201	3578	0.0145	4952	0.0201
9	3662	0.0148	5116	0.0207	3629	0.0147	5045	0.0205	3608	0.0146	5004	0.0203	3602	0.0146	4991	0.0202
10	3681	0.0149	5150	0.0209	3651	0.0148	5084	0.0206	3630	0.0147	5043	0.0205	3624	0.0147	5031	0.0204
11	3700	0.0150	5185	0.0210	3673	0.0149	5123	0.0208	3652	0.0148	5083	0.0206	3646	0.0148	5070	0.0206
12	3720	0.0151	5220	0.0212	3695	0.0150	5162	0.0209	3675	0.0149	5122	0.0208	3670	0.0149	5112	0.0207
13	3740	0.0152	5256	0.0213	3718	0.0151	5203	0.0211	3698	0.0150	5163	0.0209	3693	0.0150	5153	0.0209
14	3760	0.0152	5292	0.0215	3741	0.0152	5244	0.0213	3721	0.0151	5205	0.0211	3717	0.0151	5195	0.0211

Table H17: Heat transfer coefficients and Biot number approximations for R4-36 at 7LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3233	0.0131	4084	0.0166	3235	0.0131	4089	0.0166	3252	0.0132	4124	0.0167	3244	0.0132	4116	0.0167
2	3233	0.0131	4084	0.0166	3235	0.0131	4089	0.0166	3252	0.0132	4124	0.0167	3245	0.0132	4118	0.0167
3	3233	0.0131	4084	0.0166	3235	0.0131	4089	0.0166	3252	0.0132	4124	0.0167	3247	0.0132	4121	0.0167
4	3233	0.0131	4084	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4124	0.0167	3248	0.0132	4123	0.0167
5	3233	0.0131	4084	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4124	0.0167	3250	0.0132	4125	0.0167
6	3233	0.0131	4084	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4124	0.0167	3251	0.0132	4127	0.0167
7	3233	0.0131	4084	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4124	0.0167	3252	0.0132	4129	0.0167
8	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3254	0.0132	4132	0.0168
9	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3255	0.0132	4134	0.0168
10	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3256	0.0132	4136	0.0168
11	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3257	0.0132	4138	0.0168
12	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3259	0.0132	4140	0.0168
13	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3260	0.0132	4143	0.0168
14	3233	0.0131	4085	0.0166	3236	0.0131	4090	0.0166	3252	0.0132	4125	0.0167	3262	0.0132	4145	0.0168
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3230	0.0131	4107	0.0167	3231	0.0131	4117	0.0167	3195	0.0130	4068	0.0165	3164	0.0128	4023	0.0163
2	3235	0.0131	4115	0.0167	3237	0.0131	4126	0.0167	3205	0.0130	4084	0.0166	3177	0.0129	4045	0.0164
3	3239	0.0131	4121	0.0167	3242	0.0131	4135	0.0168	3214	0.0130	4100	0.0166	3190	0.0129	4066	0.0165
4	3243	0.0132	4128	0.0167	3248	0.0132	4144	0.0168	3224	0.0131	4116	0.0167	3204	0.0130	4087	0.0166
5	3248	0.0132	4136	0.0168	3253	0.0132	4153	0.0168	3234	0.0131	4132	0.0168	3217	0.0130	4109	0.0167
6	3252	0.0132	4143	0.0168	3259	0.0132	4162	0.0169	3244	0.0132	4149	0.0168	3230	0.0131	4131	0.0167
7	3256	0.0132	4150	0.0168	3264	0.0132	4170	0.0169	3254	0.0132	4165	0.0169	3244	0.0132	4153	0.0168
8	3261	0.0132	4157	0.0169	3270	0.0133	4180	0.0169	3265	0.0132	4182	0.0170	3258	0.0132	4175	0.0169
9	3265	0.0132	4164	0.0169	3275	0.0133	4189	0.0170	3275	0.0133	4198	0.0170	3272	0.0133	4198	0.0170
10	3270	0.0133	4171	0.0169	3281	0.0133	4198	0.0170	3285	0.0133	4216	0.0171	3286	0.0133	4221	0.0171
11	3274	0.0133	4179	0.0169	3287	0.0133	4207	0.0171	3296	0.0134	4233	0.0172	3300	0.0134	4244	0.0172
12	3278	0.0133	4185	0.0170	3292	0.0133	4216	0.0171	3306	0.0134	4250	0.0172	3314	0.0134	4268	0.0173
13	3282	0.0133	4191	0.0170	3297	0.0134	4224	0.0171	3316	0.0134	4266	0.0173	3328	0.0135	4290	0.0174
14	3286	0.0133	4198	0.0170	3302	0.0134	4232	0.0172	3326	0.0135	4282	0.0174	3341	0.0135	4311	0.0175
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	3134	0.0127	3987	0.0162	3082	0.0125	3905	0.0158	3064	0.0124	3880	0.0157	3054	0.0124	3862	0.0157
2	3150	0.0128	4013	0.0163	3098	0.0126	3929	0.0159	3084	0.0125	3913	0.0159	3078	0.0125	3903	0.0158
3	3166	0.0128	4039	0.0164	3114	0.0126	3954	0.0160	3102	0.0126	3941	0.0160	3099	0.0126	3935	0.0160
4	3183	0.0129	4064	0.0165	3130	0.0127	3979	0.0161	3120	0.0127	3969	0.0161	3119	0.0126	3967	0.0161
5	3200	0.0130	4091	0.0166	3146	0.0128	4005	0.0162	3138	0.0127	3998	0.0162	3140	0.0127	3999	0.0162
6	3216	0.0130	4118	0.0167	3163	0.0128	4031	0.0163	3156	0.0128	4027	0.0163	3161	0.0128	4033	0.0164
7	3232	0.0131	4144	0.0168	3179	0.0129	4057	0.0165	3175	0.0129	4056	0.0164	3182	0.0129	4066	0.0165
8	3249	0.0132	4171	0.0169	3196	0.0130	4083	0.0166	3194	0.0130	4086	0.0166	3204	0.0130	4101	0.0166
9	3265	0.0132	4198	0.0170	3212	0.0130	4109	0.0167	3213	0.0130	4116	0.0167	3225	0.0131	4135	0.0168
10	3283	0.0133	4226	0.0171	3229	0.0131	4136	0.0168	3232	0.0131	4146	0.0168	3247	0.0132	4170	0.0169
11	3300	0.0134	4255	0.0173	3245	0.0132	4163	0.0169	3250	0.0132	4177	0.0169	3268	0.0133	4205	0.0171
12	3317	0.0135	4283	0.0174	3262	0.0132	4191	0.0170	3269	0.0133	4208	0.0171	3290	0.0133	4241	0.0172
13	3335	0.0135	4313	0.0175	3280	0.0133	4219	0.0171	3289	0.0133	4240	0.0172	3313	0.0134	4279	0.0173
14	3351	0.0136	4340	0.0176	3297	0.0134	4247	0.0172	3309	0.0134	4273	0.0173	3336	0.0135	4316	0.0175

Table H18: Heat transfer coefficients and Biot number approximations for R4-36 at 5.5LPM

Coilset	1 second				2 seconds				3 seconds				5 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	2890	0.0117	3384	0.0137	2887	0.0117	3383	0.0137	2882	0.0117	3375	0.0137	2880	0.0117	3376	0.0137
2	2890	0.0117	3385	0.0137	2888	0.0117	3384	0.0137	2884	0.0117	3377	0.0137	2883	0.0117	3380	0.0137
3	2891	0.0117	3386	0.0137	2890	0.0117	3386	0.0137	2885	0.0117	3379	0.0137	2885	0.0117	3384	0.0137
4	2891	0.0117	3387	0.0137	2890	0.0117	3387	0.0137	2887	0.0117	3381	0.0137	2887	0.0117	3387	0.0137
5	2892	0.0117	3388	0.0137	2891	0.0117	3388	0.0137	2888	0.0117	3383	0.0137	2890	0.0117	3391	0.0137
6	2892	0.0117	3389	0.0137	2892	0.0117	3390	0.0137	2889	0.0117	3385	0.0137	2892	0.0117	3395	0.0138
7	2893	0.0117	3390	0.0137	2893	0.0117	3391	0.0138	2891	0.0117	3387	0.0137	2895	0.0117	3398	0.0138
8	2894	0.0117	3391	0.0137	2894	0.0117	3393	0.0138	2892	0.0117	3389	0.0137	2897	0.0117	3402	0.0138
9	2895	0.0117	3392	0.0138	2895	0.0117	3394	0.0138	2893	0.0117	3391	0.0138	2899	0.0118	3405	0.0138
10	2895	0.0117	3393	0.0138	2896	0.0117	3395	0.0138	2894	0.0117	3393	0.0138	2901	0.0118	3409	0.0138
11	2896	0.0117	3394	0.0138	2897	0.0117	3397	0.0138	2896	0.0117	3395	0.0138	2903	0.0118	3412	0.0138
12	2896	0.0117	3395	0.0138	2898	0.0118	3398	0.0138	2897	0.0117	3397	0.0138	2906	0.0118	3415	0.0138
13	2897	0.0117	3396	0.0138	2899	0.0118	3400	0.0138	2898	0.0118	3399	0.0138	2908	0.0118	3418	0.0139
14	2897	0.0117	3396	0.0138	2900	0.0118	3401	0.0138	2900	0.0118	3401	0.0138	2910	0.0118	3421	0.0139
Coilset	8 seconds				10 seconds				15 seconds				20 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	2875	0.0117	3376	0.0137	2855	0.0116	3348	0.0136	2849	0.0116	3353	0.0136	2825	0.0115	3319	0.0135
2	2879	0.0117	3382	0.0137	2861	0.0116	3357	0.0136	2857	0.0116	3366	0.0136	2836	0.0115	3335	0.0135
3	2883	0.0117	3388	0.0137	2866	0.0116	3365	0.0136	2866	0.0116	3379	0.0137	2847	0.0115	3351	0.0136
4	2887	0.0117	3394	0.0138	2872	0.0116	3373	0.0137	2874	0.0117	3392	0.0138	2857	0.0116	3367	0.0137
5	2891	0.0117	3400	0.0138	2878	0.0117	3382	0.0137	2883	0.0117	3404	0.0138	2869	0.0116	3384	0.0137
6	2895	0.0117	3406	0.0138	2883	0.0117	3390	0.0137	2892	0.0117	3417	0.0139	2880	0.0117	3401	0.0138
7	2898	0.0118	3412	0.0138	2889	0.0117	3398	0.0138	2900	0.0118	3431	0.0139	2891	0.0117	3418	0.0139
8	2903	0.0118	3418	0.0139	2894	0.0117	3407	0.0138	2909	0.0118	3444	0.0140	2902	0.0118	3435	0.0139
9	2906	0.0118	3423	0.0139	2900	0.0118	3416	0.0139	2918	0.0118	3458	0.0140	2914	0.0118	3452	0.0140
10	2911	0.0118	3430	0.0139	2906	0.0118	3424	0.0139	2927	0.0119	3471	0.0141	2925	0.0119	3470	0.0141
11	2915	0.0118	3436	0.0139	2912	0.0118	3433	0.0139	2936	0.0119	3485	0.0141	2937	0.0119	3488	0.0141
12	2918	0.0118	3441	0.0140	2917	0.0118	3441	0.0140	2945	0.0119	3499	0.0142	2949	0.0120	3505	0.0142
13	2922	0.0118	3446	0.0140	2922	0.0119	3449	0.0140	2954	0.0120	3511	0.0142	2960	0.0120	3522	0.0143
14	2925	0.0119	3451	0.0140	2928	0.0119	3457	0.0140	2962	0.0120	3524	0.0143	2970	0.0120	3537	0.0143
Coilset	30 seconds				50 seconds				100 seconds				200 seconds			
	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}	h_{lam}	Bi_{lam}	h_{turb}	Bi_{turb}
1	2803	0.0114	3301	0.0134	2815	0.0114	3352	0.0136	2728	0.0111	3196	0.0130	2712	0.0110	3169	0.0129
2	2818	0.0114	3323	0.0135	2830	0.0115	3373	0.0137	2747	0.0111	3225	0.0131	2732	0.0111	3201	0.0130
3	2833	0.0115	3344	0.0136	2845	0.0115	3395	0.0138	2761	0.0112	3245	0.0132	2750	0.0112	3228	0.0131
4	2848	0.0115	3366	0.0136	2860	0.0116	3417	0.0139	2776	0.0113	3267	0.0132	2765	0.0112	3250	0.0132
5	2862	0.0116	3388	0.0137	2875	0.0117	3440	0.0139	2790	0.0113	3288	0.0133	2780	0.0113	3272	0.0133
6	2877	0.0117	3410	0.0138	2891	0.0117	3463	0.0140	2805	0.0114	3309	0.0134	2796	0.0113	3295	0.0134
7	2892	0.0117	3433	0.0139	2907	0.0118	3487	0.0141	2820	0.0114	3331	0.0135	2812	0.0114	3318	0.0135
8	2907	0.0118	3455	0.0140	2923	0.0119	3510	0.0142	2835	0.0115	3353	0.0136	2828	0.0115	3342	0.0135
9	2922	0.0118	3478	0.0141	2938	0.0119	3534	0.0143	2851	0.0116	3376	0.0137	2844	0.0115	3365	0.0136
10	2938	0.0119	3502	0.0142	2954	0.0120	3557	0.0144	2866	0.0116	3398	0.0138	2861	0.0116	3389	0.0137
11	2954	0.0120	3526	0.0143	2969	0.0120	3582	0.0145	2881	0.0117	3421	0.0139	2877	0.0117	3413	0.0138
12	2969	0.0120	3550	0.0144	2985	0.0121	3606	0.0146	2896	0.0117	3444	0.0140	2893	0.0117	3437	0.0139
13	2985	0.0121	3573	0.0145	3001	0.0122	3631	0.0147	2912	0.0118	3467	0.0141	2909	0.0118	3462	0.0140
14	2999	0.0122	3595	0.0146	3018	0.0122	3656	0.0148	2927	0.0119	3491	0.0142	2926	0.0119	3487	0.0141

Appendix I: Surface and Water Temperature Profiles across Non-Dimensionalized DWHR System Length

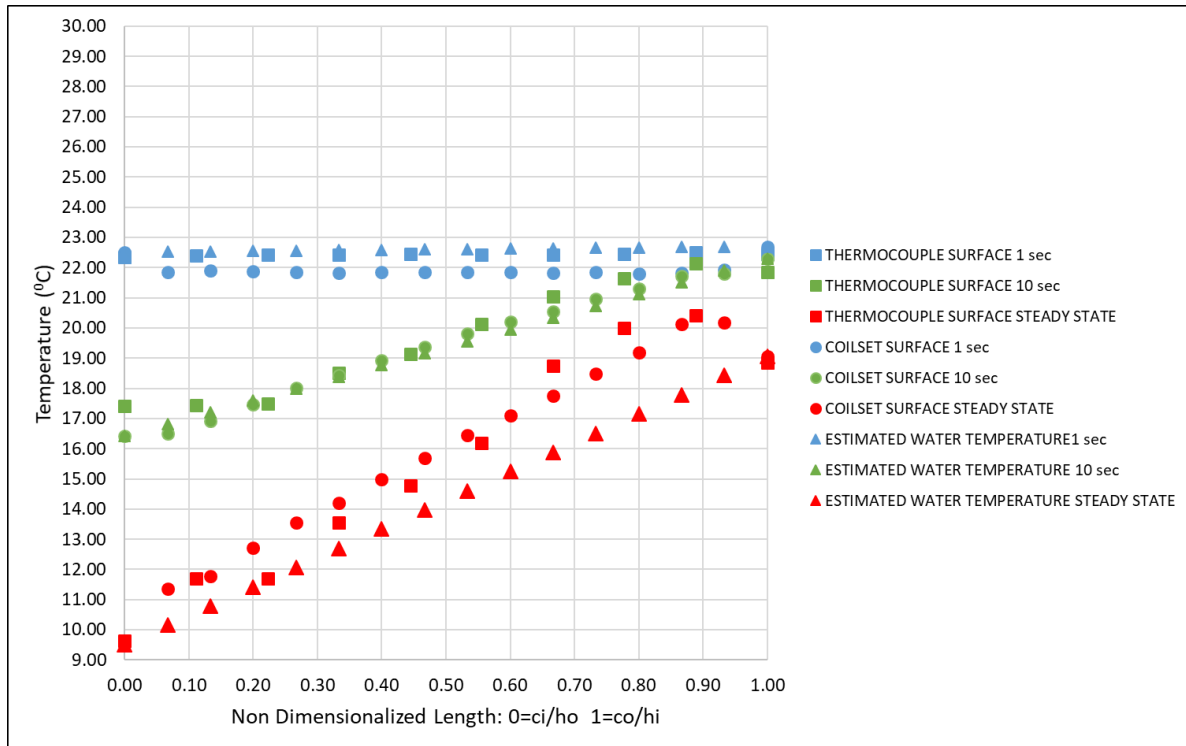


Figure I1: Mains-side temperature profiles at different time instants for R3-36 at 14LPM

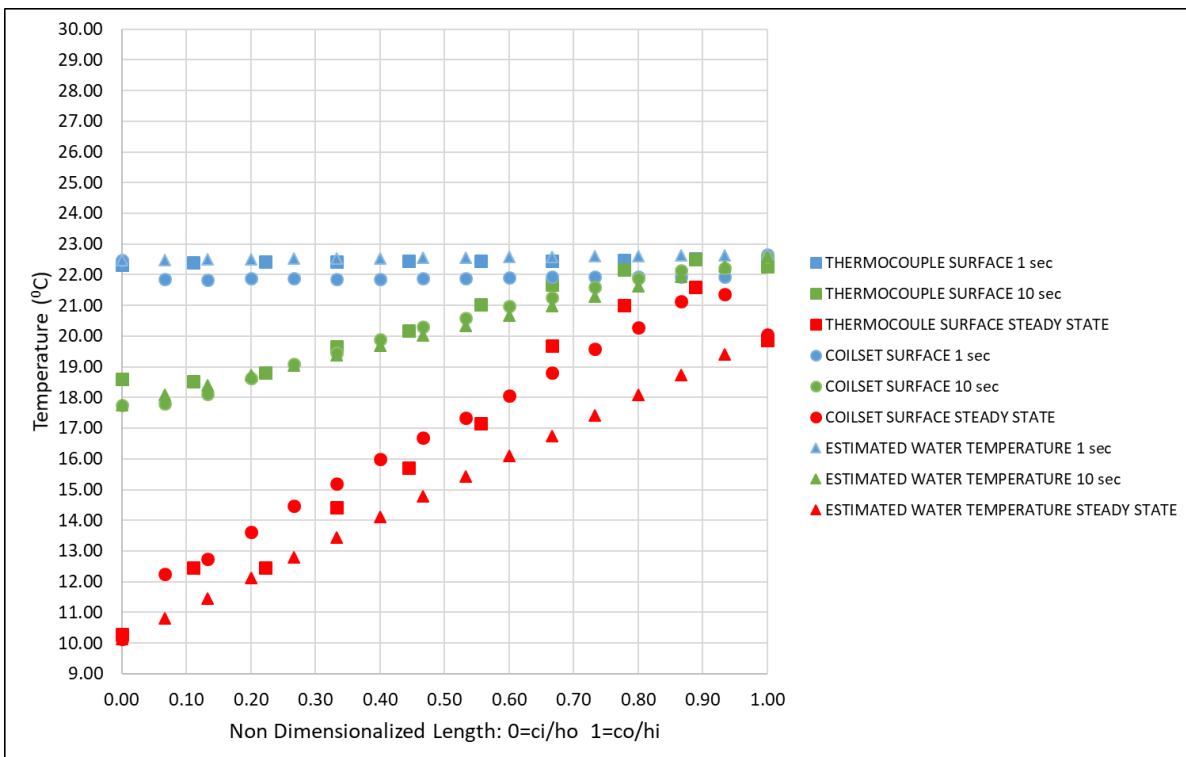


Figure I2: Mains-side temperature profiles at different time instants for R3-36 at 12LPM

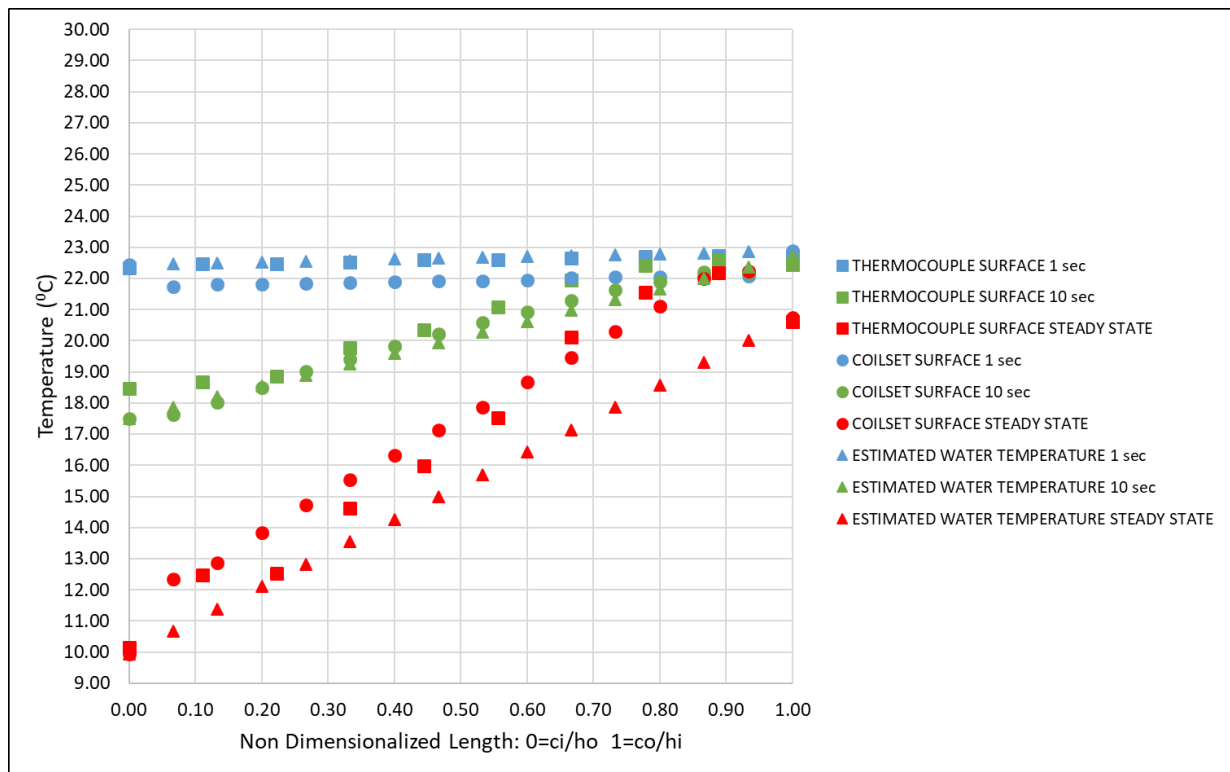


Figure I3: Mains-side temperature profiles at different time instants for R3-36 at 10LPM

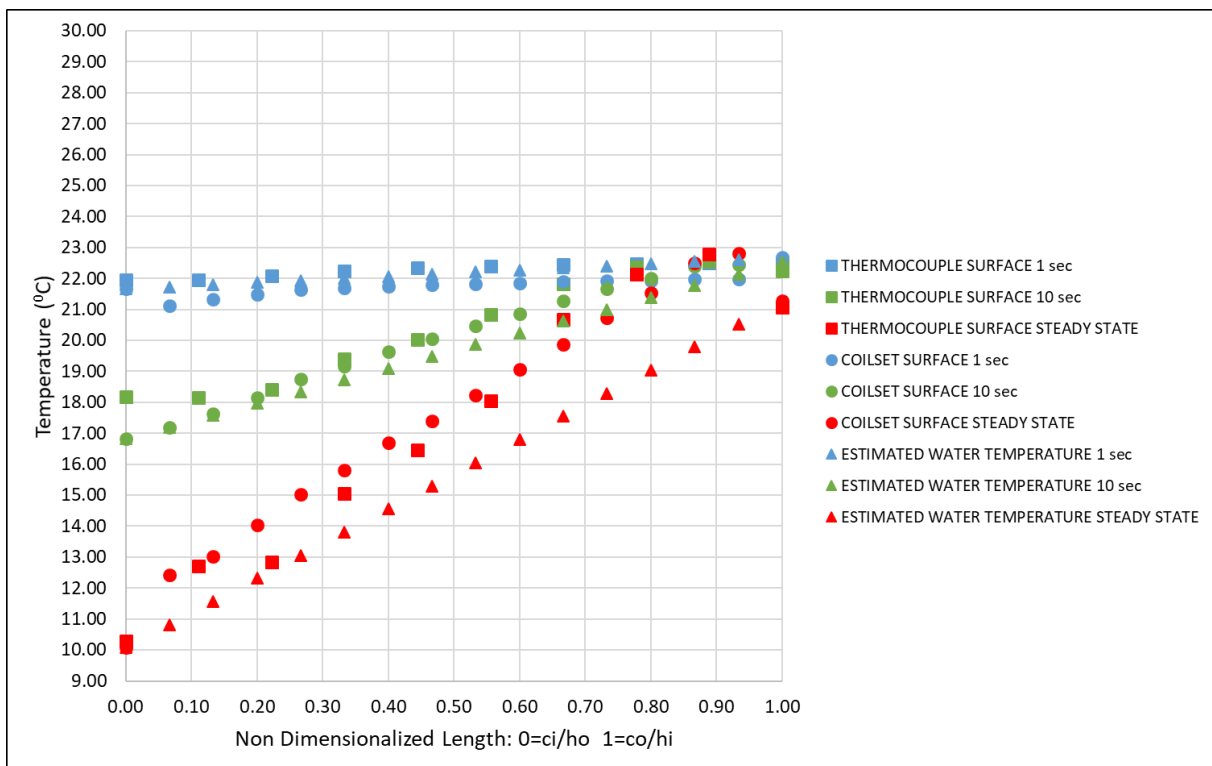


Figure I4: Mains-side temperature profiles at different time instants for R3-36 at 9LPM

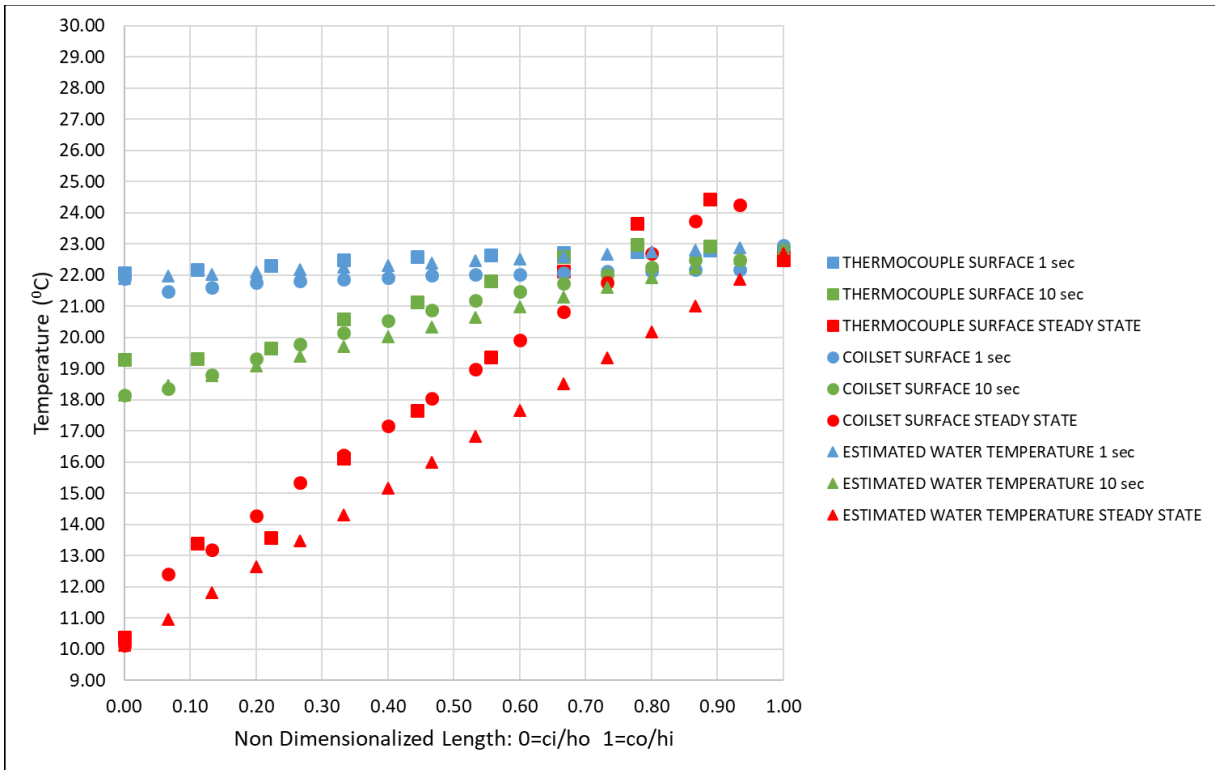


Figure I5: Mains-side temperature profiles at different time instants for R3-36 at 7LPM

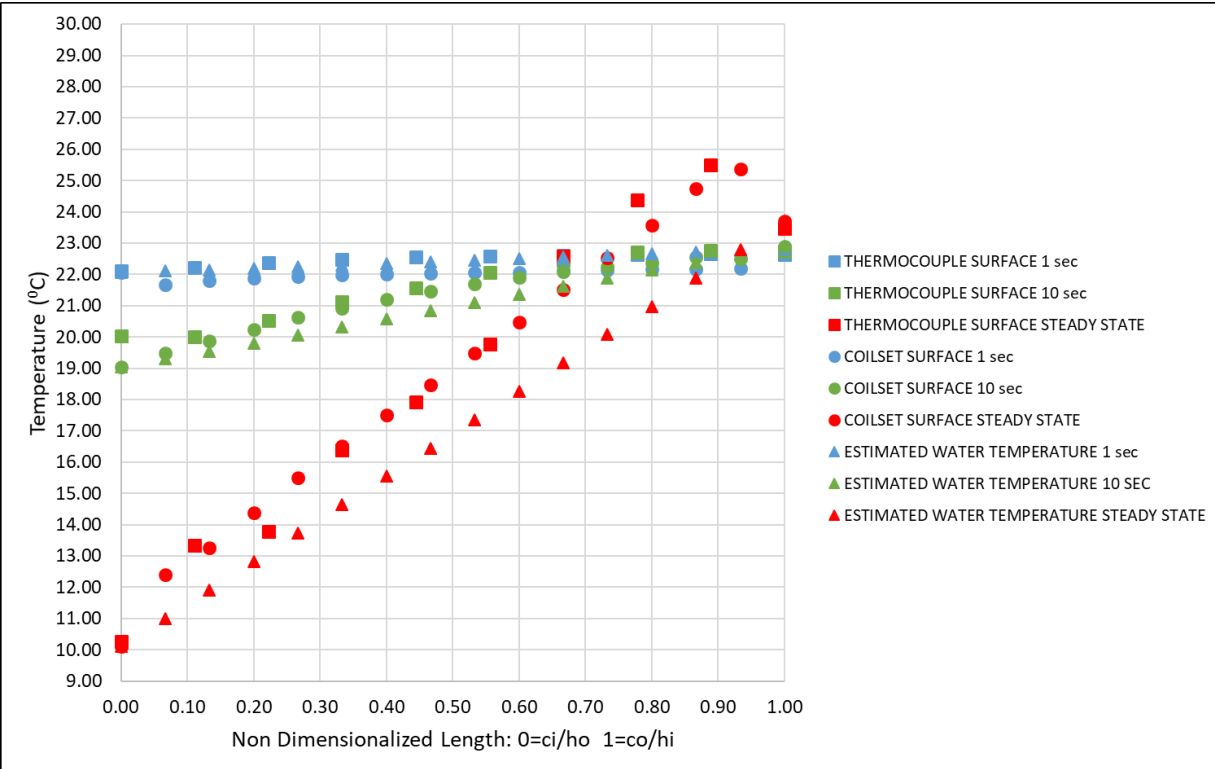


Figure I6: Mains-side temperature profiles at different time instants for R3-36 at 5.5LPM

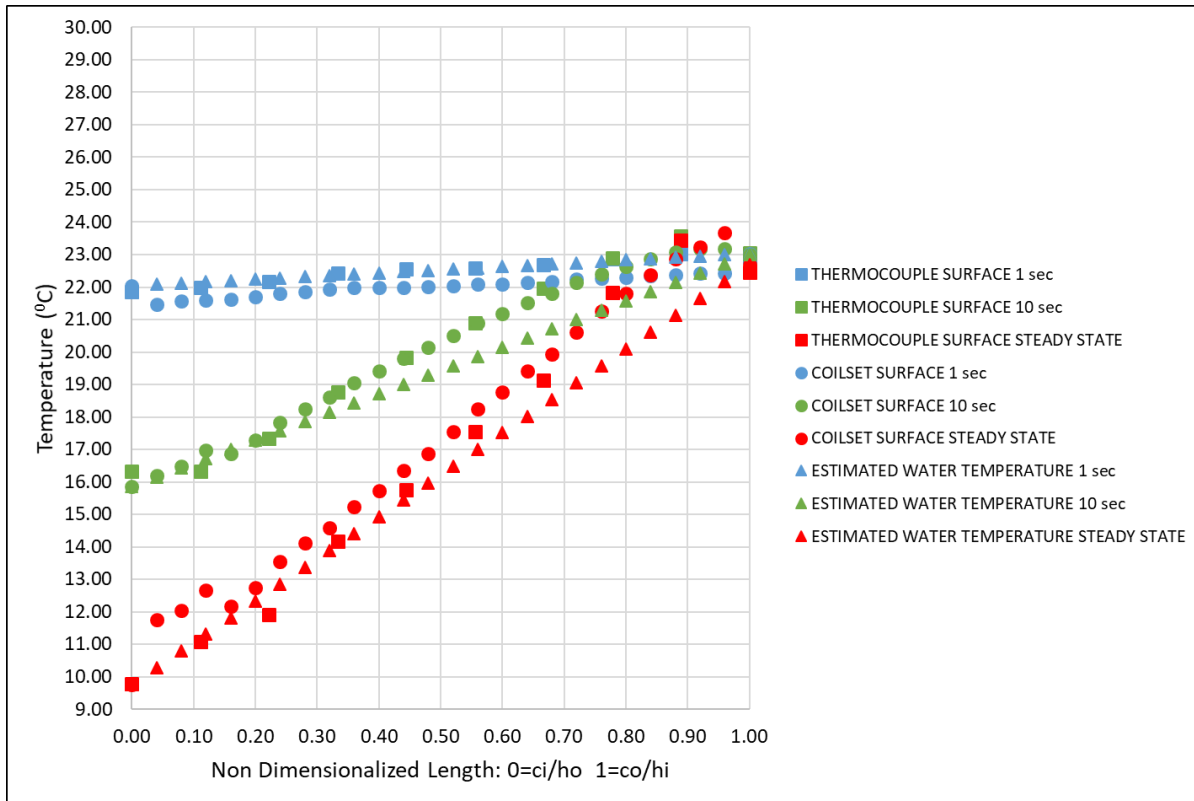


Figure I7: Mains-side temperature profiles at different time instants for R3-60 at 14LPM

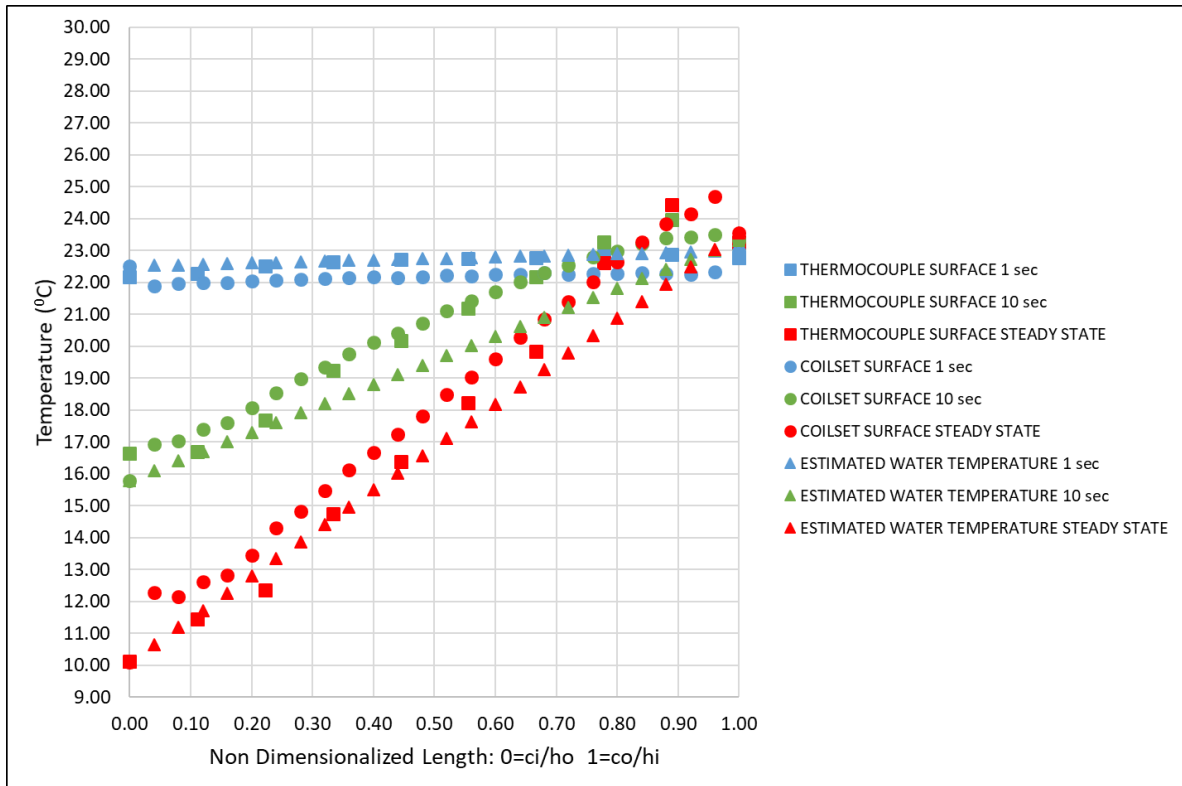


Figure I8: Mains-side temperature profiles at different time instants for R3-60 at 12LPM

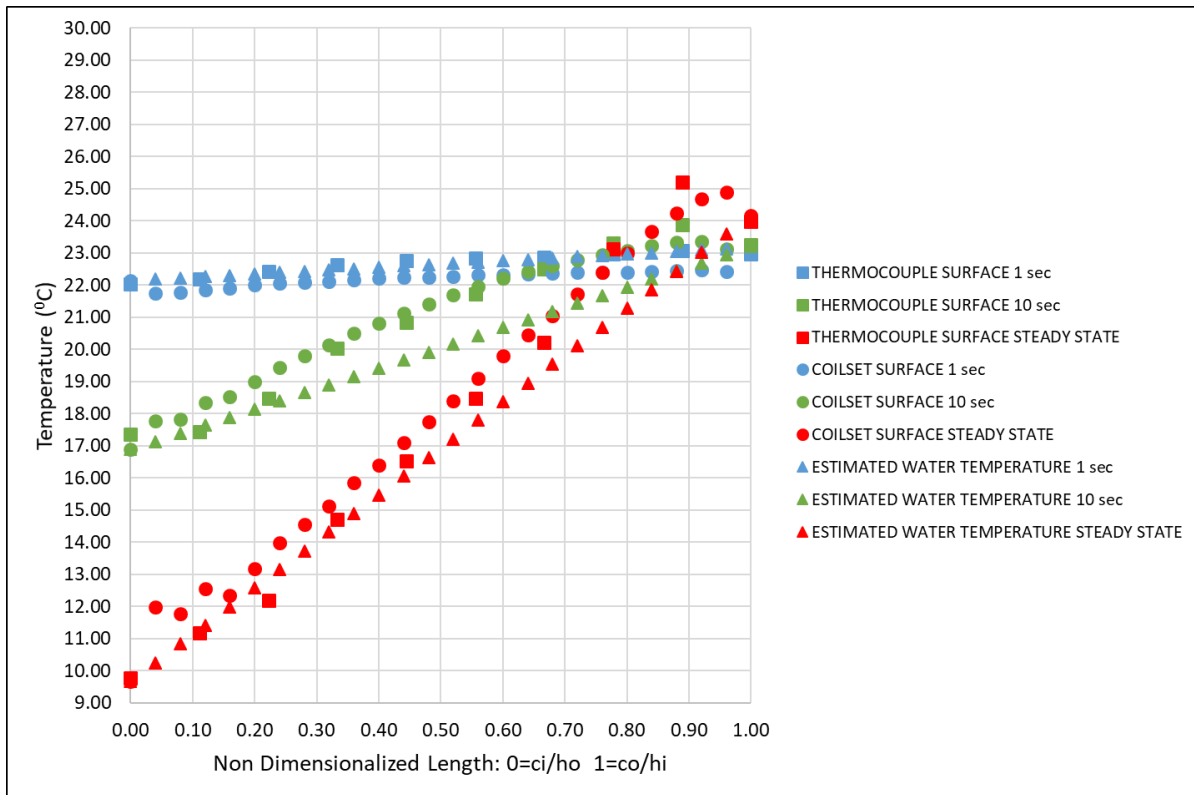


Figure I9: Mains-side temperature profiles at different time instants for R3-60 at 10LPM

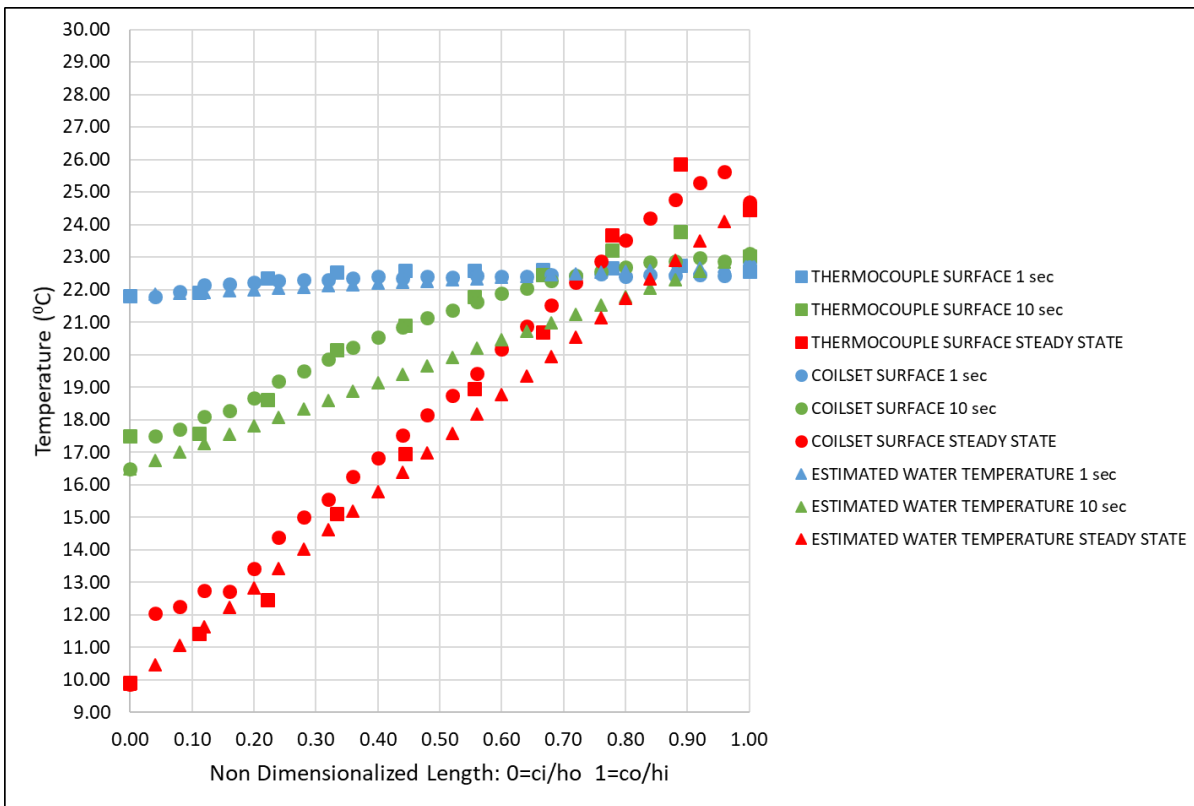


Figure I10: Mains-side temperature profiles at different time instants for R3-60 at 9LPM

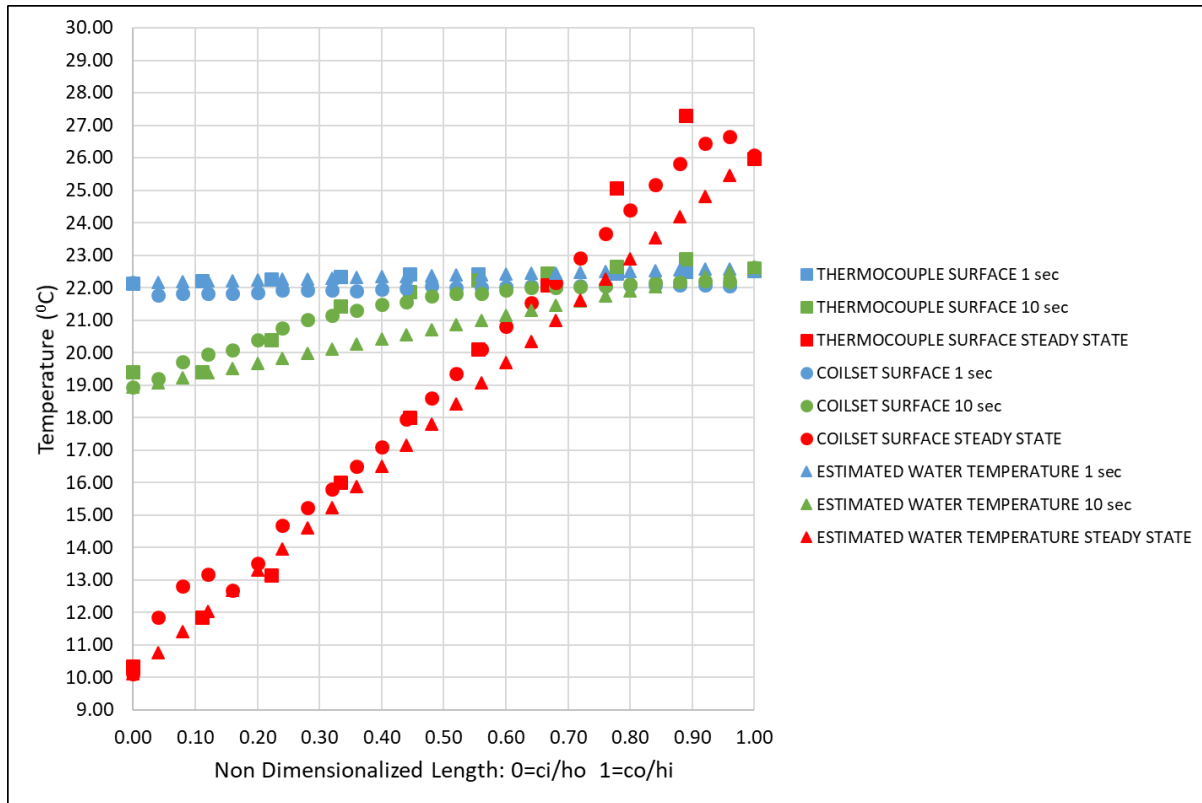


Figure I11: Mains-side temperature profiles at different time instants for R3-60 at 7LPM

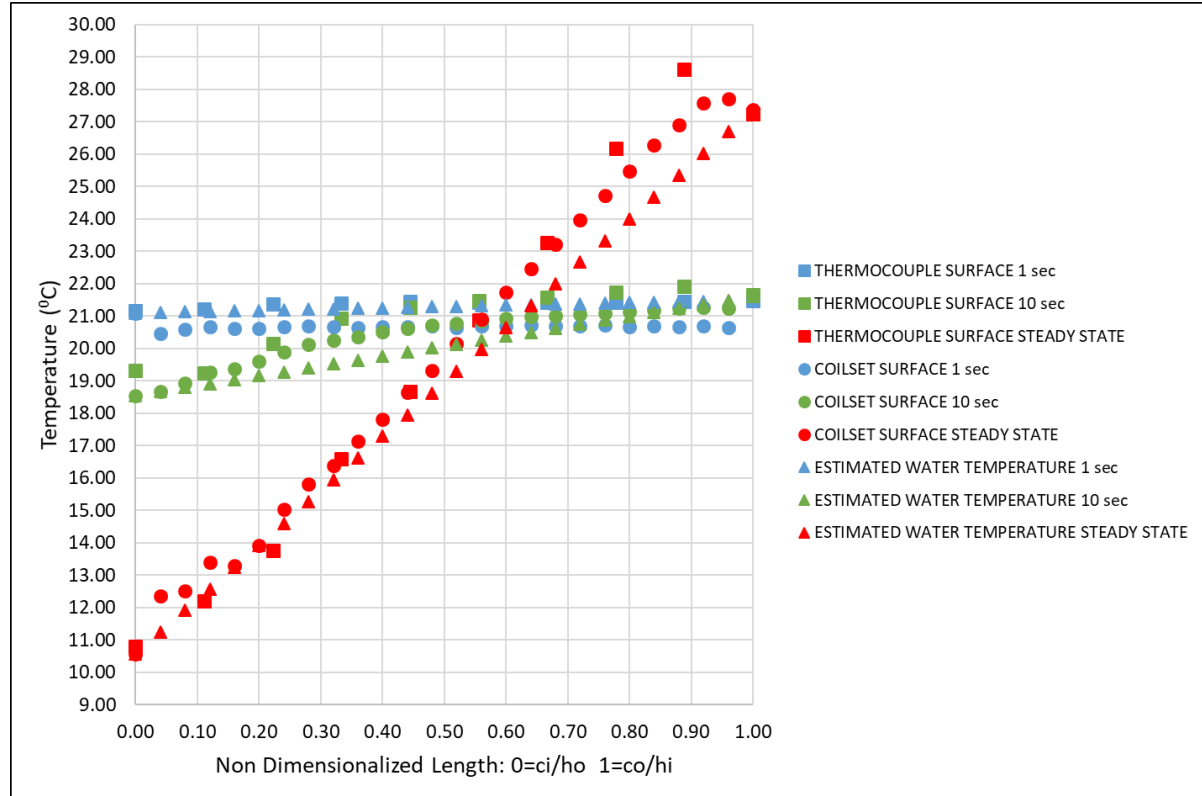


Figure I12: Mains-side temperature profiles at different time instants for R3-60 at 5.5LPM

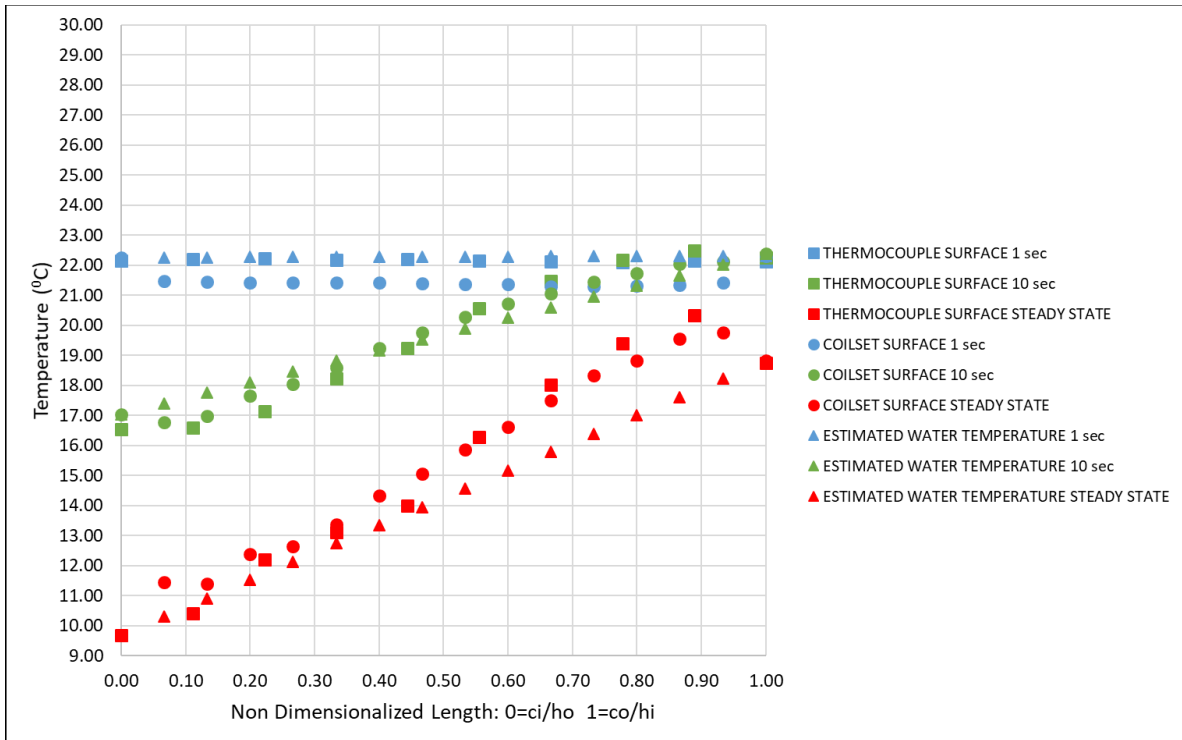


Figure I13: Mains-side temperature profiles at different time instants for R4-36 at 14LPM

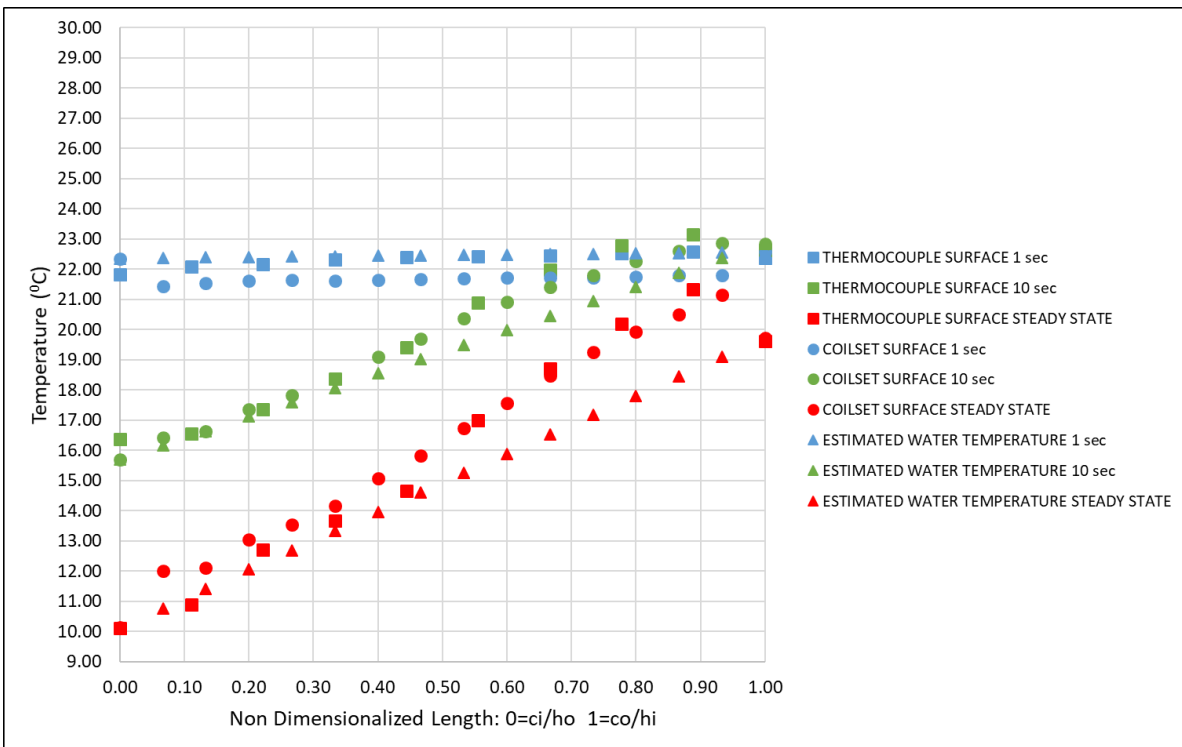


Figure I14: Mains-side temperature profiles at different time instants for R4-36 at 12LPM

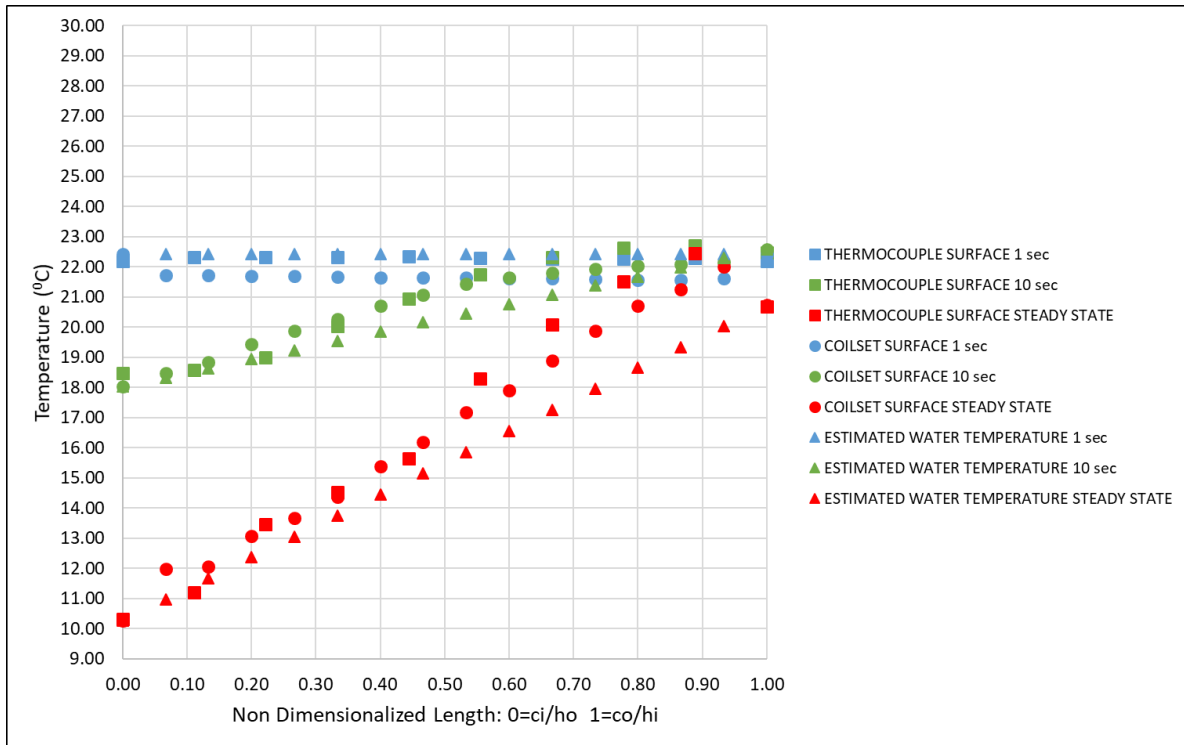


Figure I15: Mains-side temperature profiles at different time instants for R4-36 at 10LPM

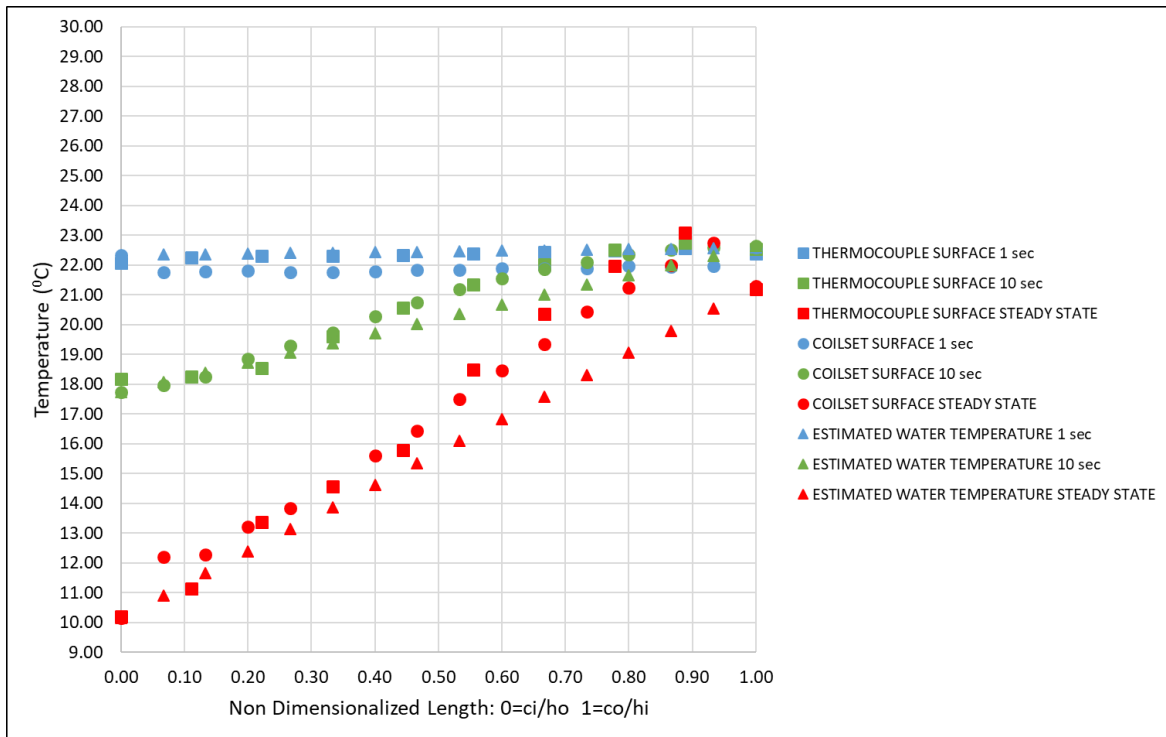


Figure I16: Mains-side temperature profiles at different time instants for R4-36 at 9LPM

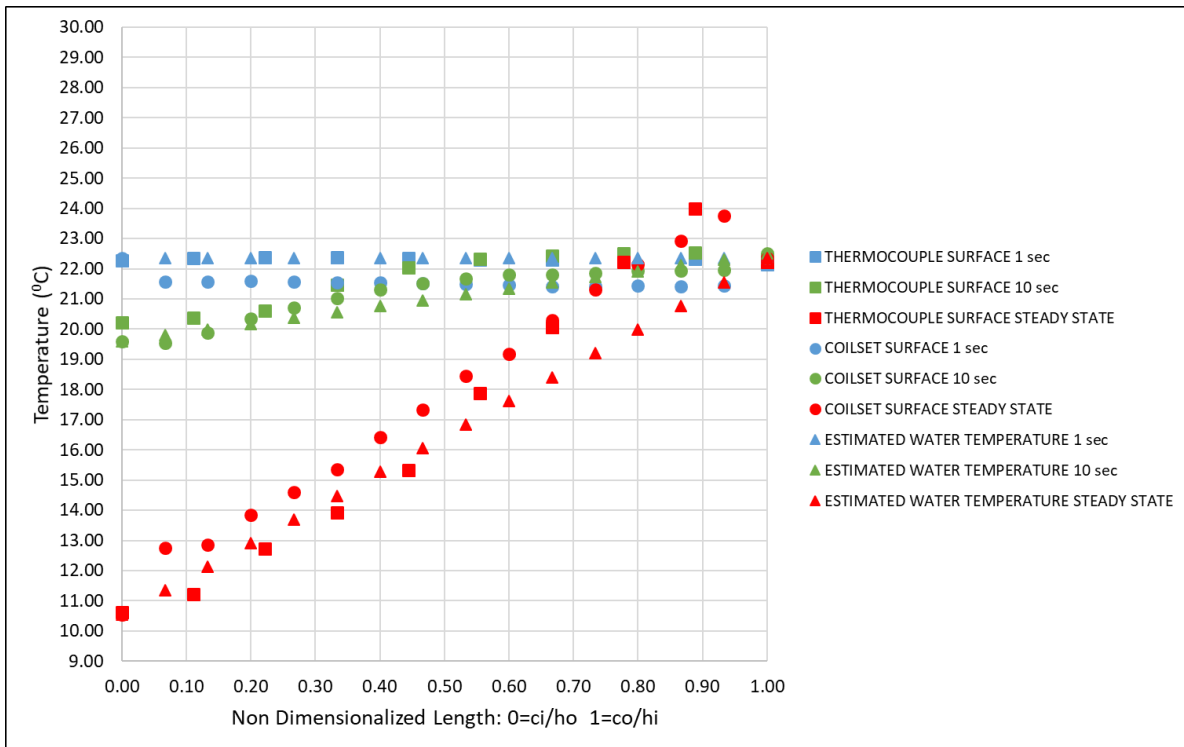


Figure I17: Mains-side temperature profiles at different time instants for R4-36 at 7LPM

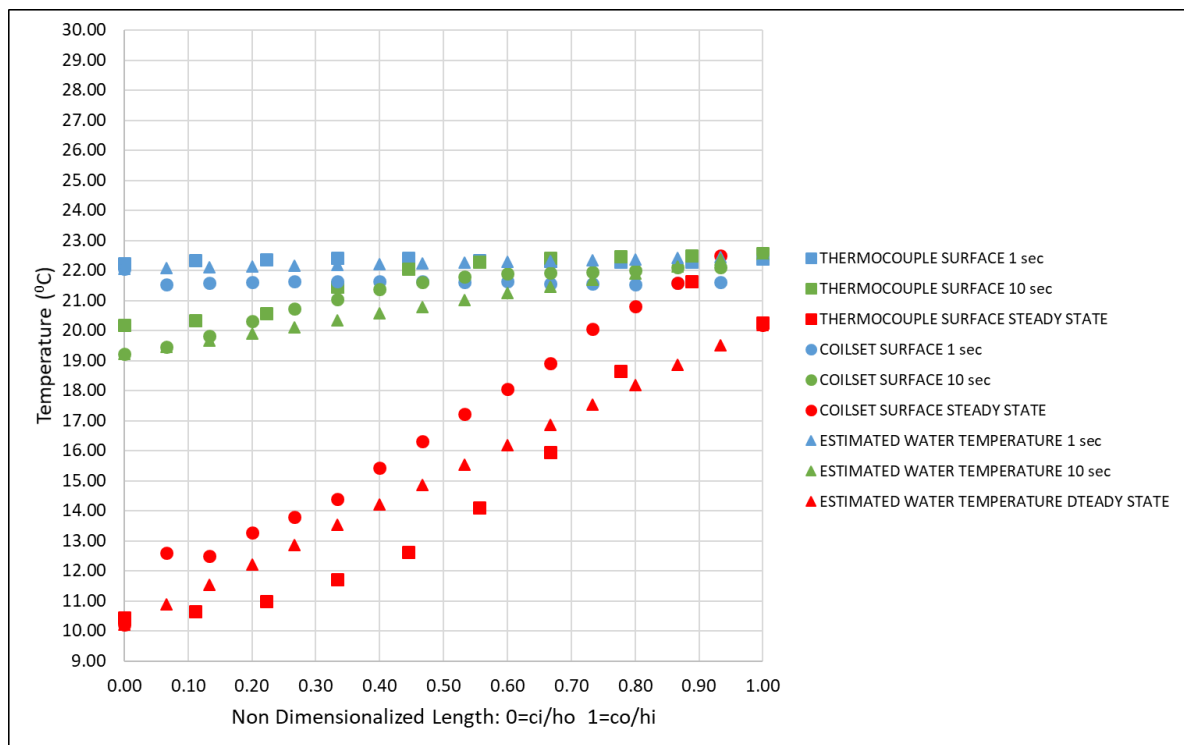


Figure I18: Mains-side temperature profiles at different time instants for R4-36 at 5.5LPM

Appendix J: Surface and Water Temperature Profiles across Entire Test Duration

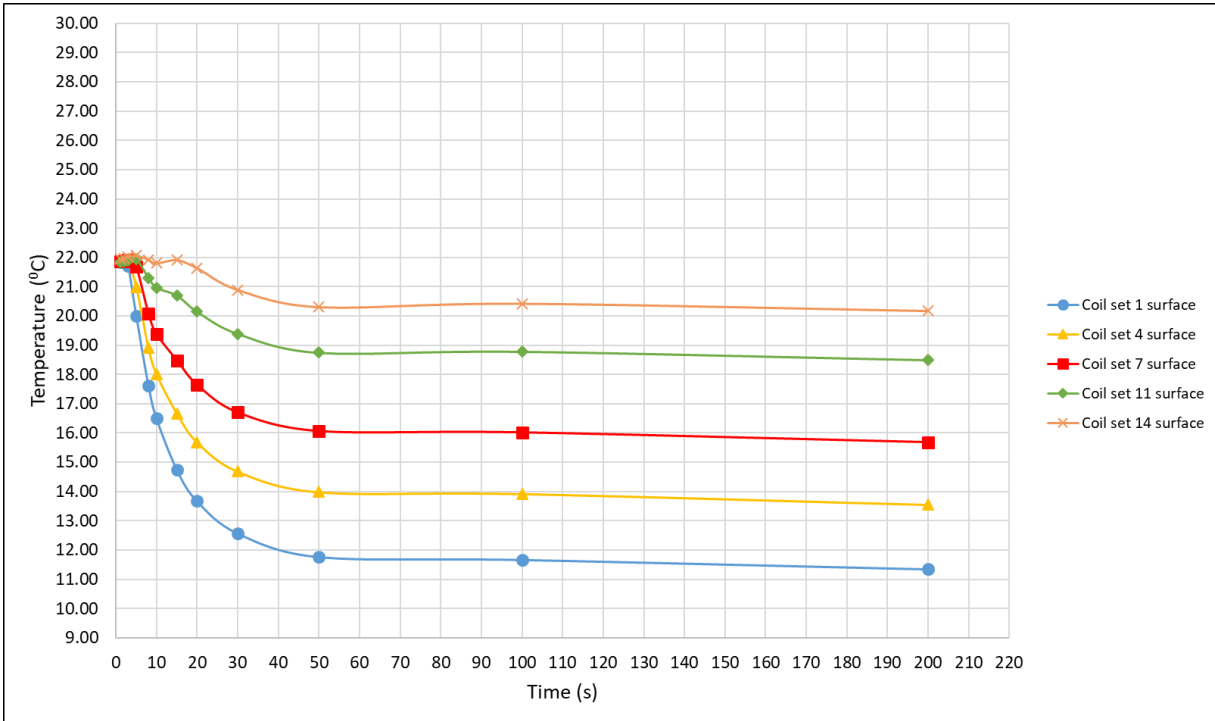


Figure J1: Coil set surface temperature profiles at different time instants for R3-36 at 14LPM

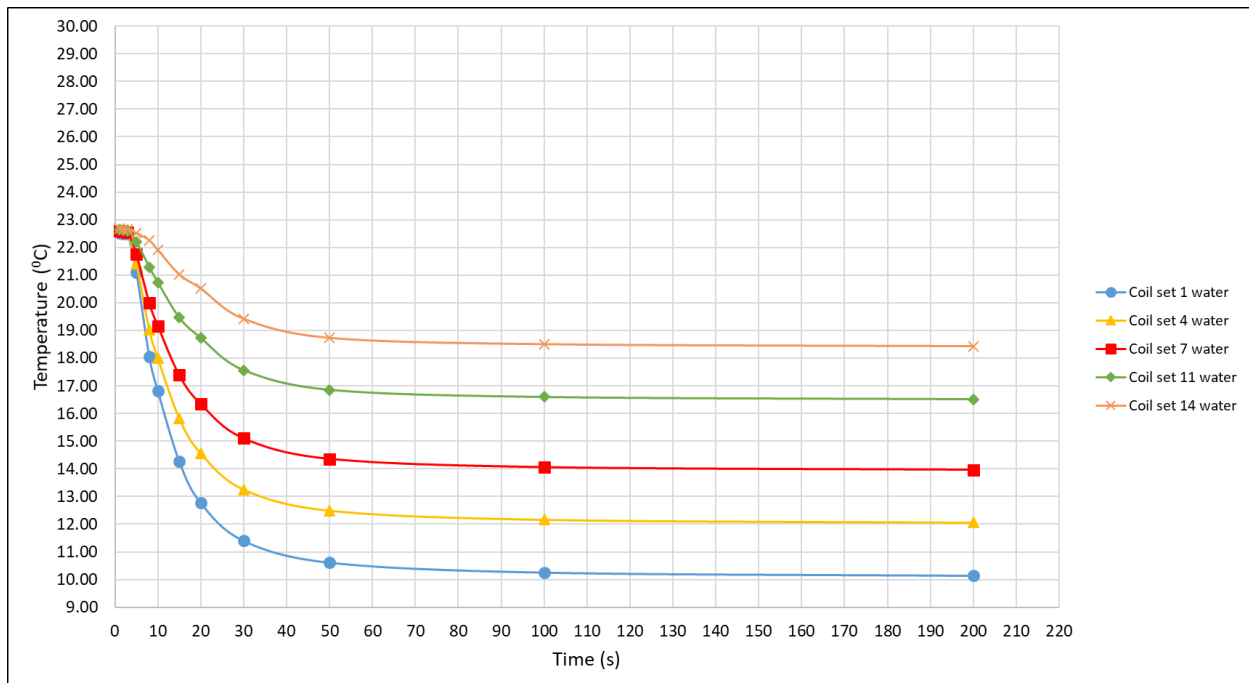


Figure J2: Estimated coil set water temperature profiles at different time instants for R3-36 at 14LPM

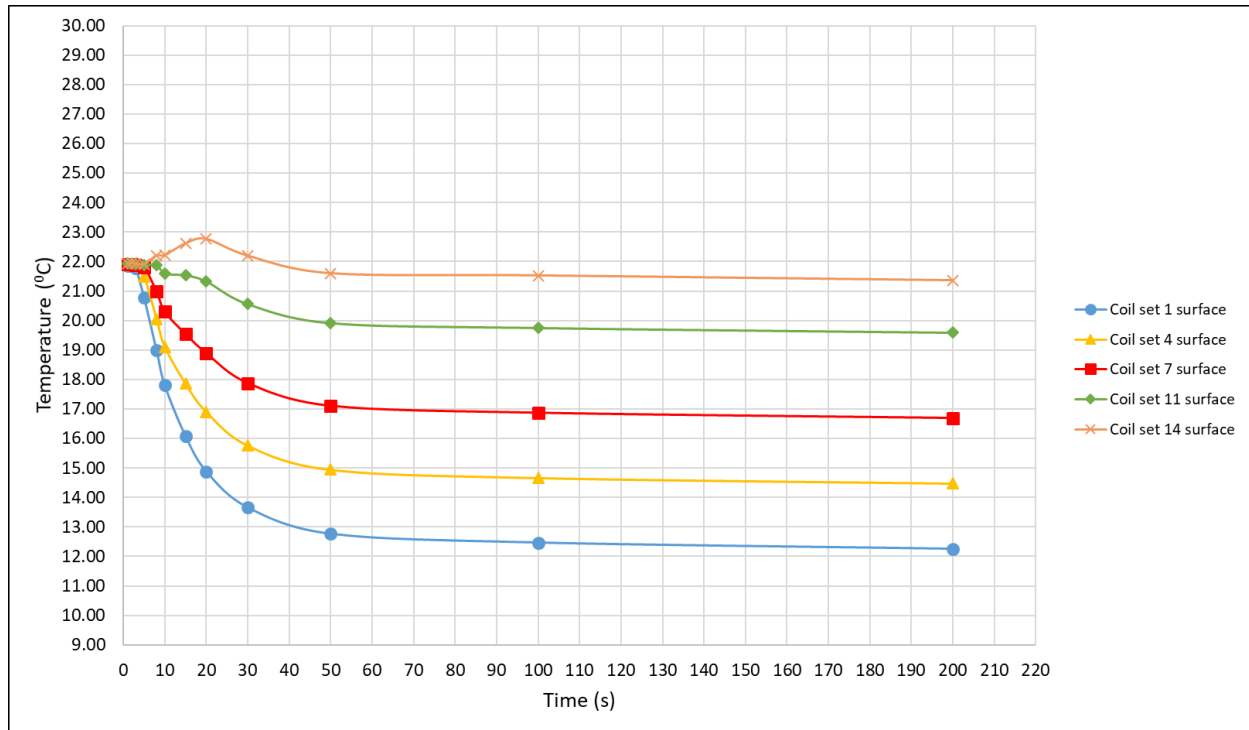


Figure J3: Coil set surface temperature profiles at different time instants for R3-36 at 12LPM

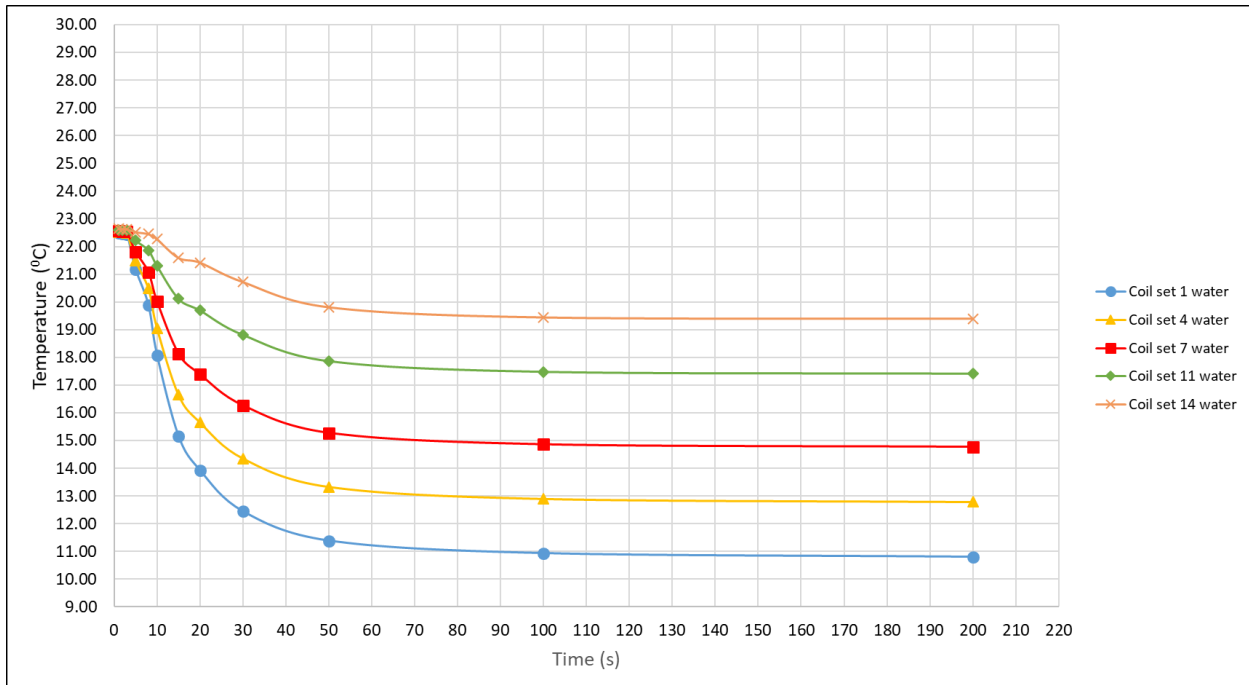


Figure J4: Estimated coil set water temperature profiles at different time instants for R3-36 at 12LPM

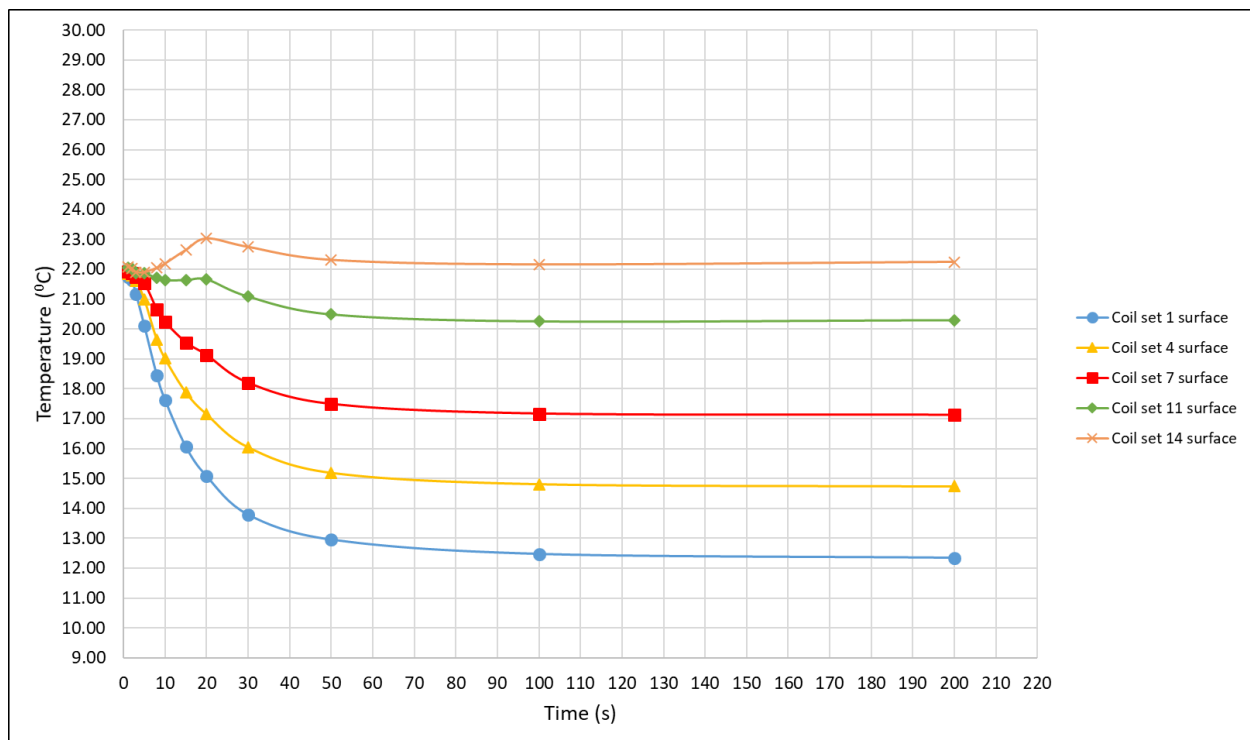


Figure J5: Coil set surface temperature profiles at different time instants for R3-36 at 10LPM

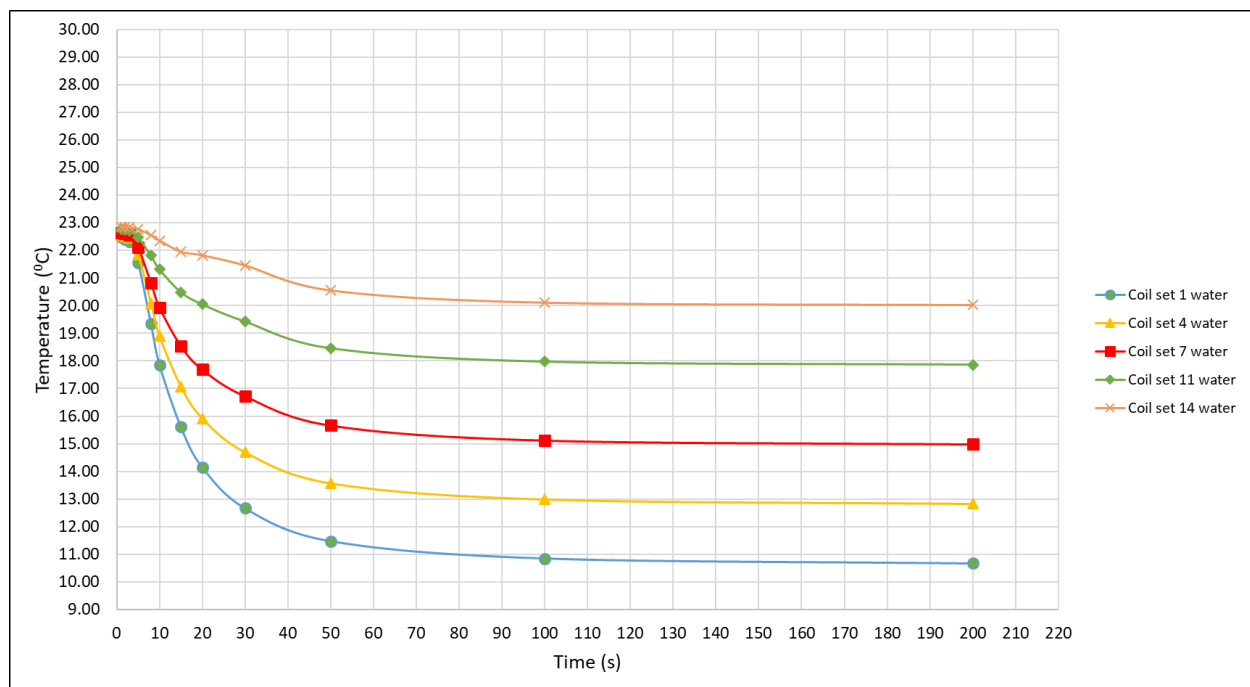


Figure J6: Estimated coil set water temperature profiles at different time instants for R3-36 at 10LPM

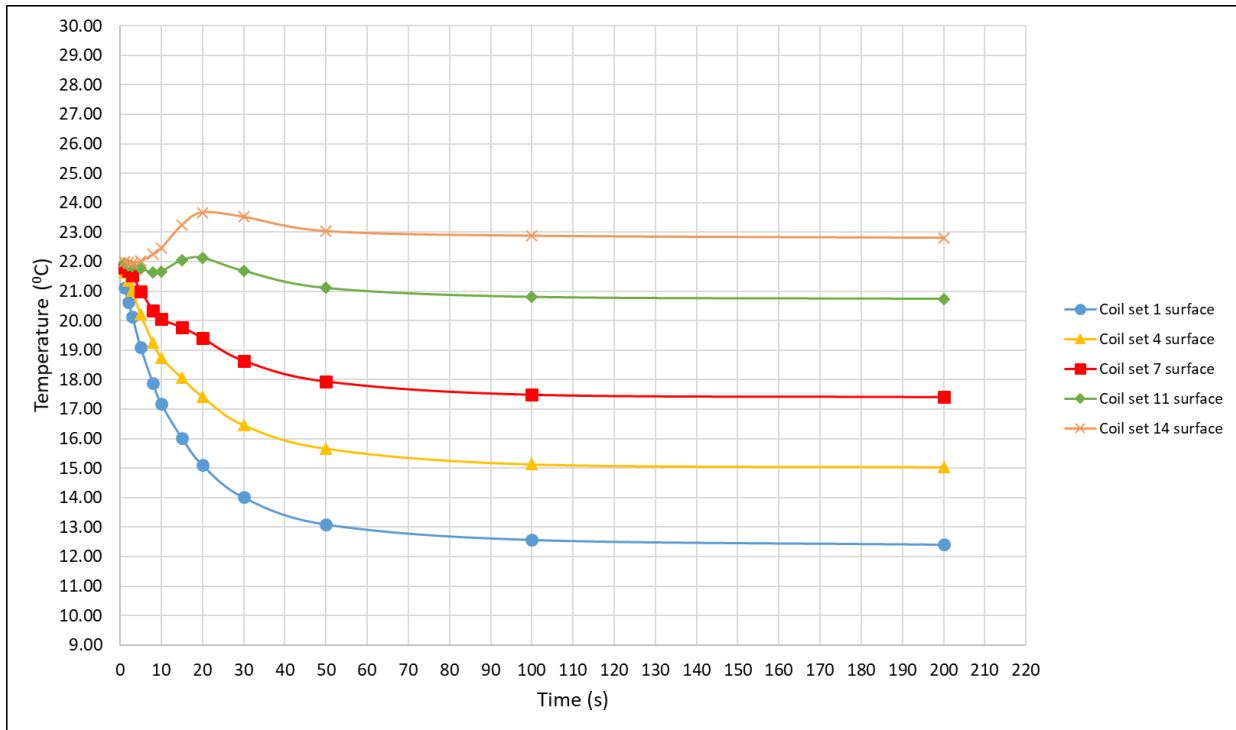


Figure J7: Coil set surface temperature profiles at different time instants for R3-36 at 9LPM

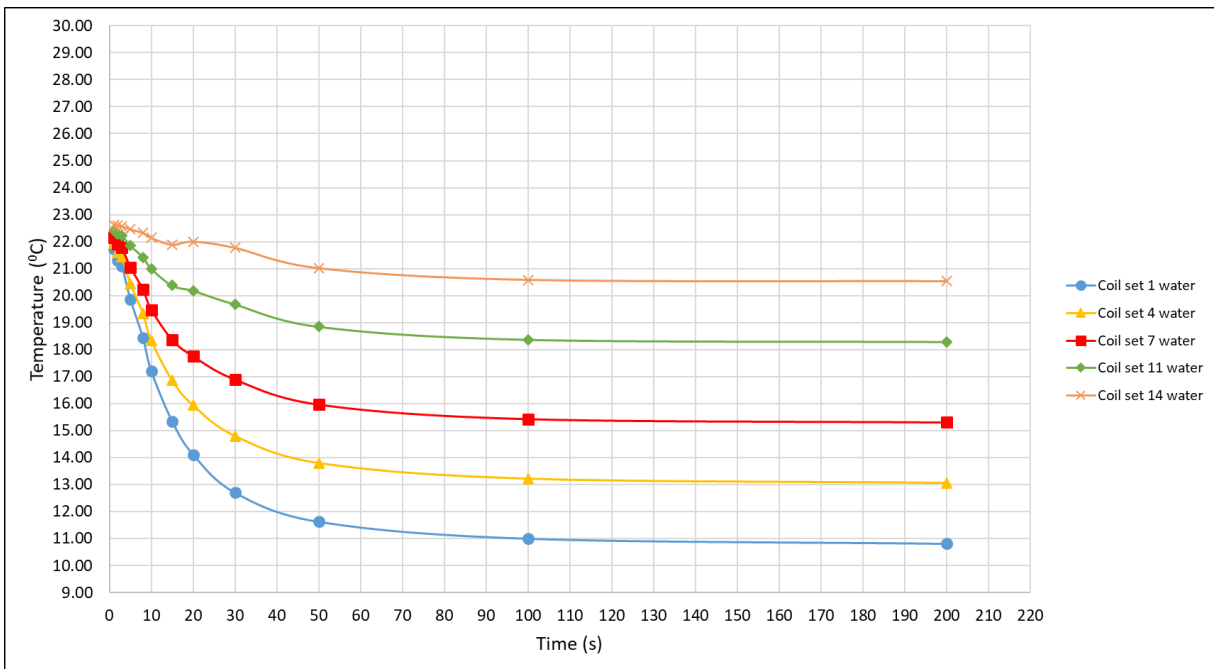


Figure J8: Estimated coil set water temperature profiles at different time instants for R3-36 at 9LPM

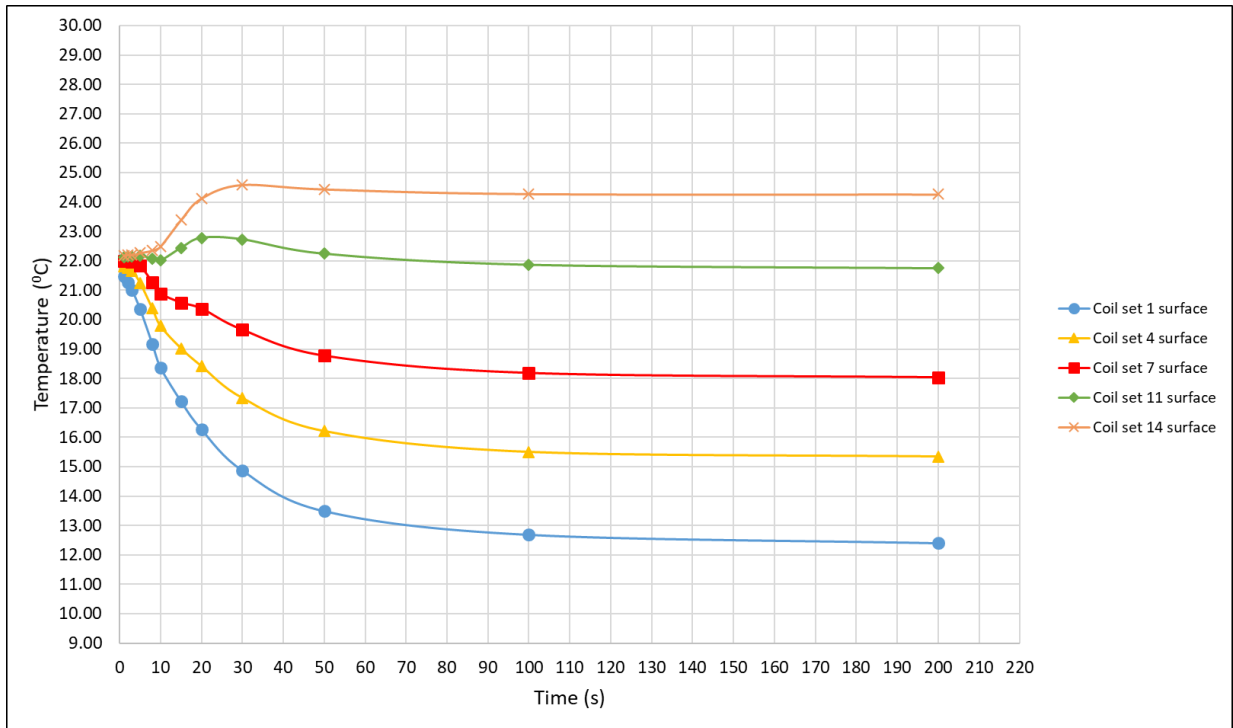


Figure J9: Coil set surface temperature profiles at different time instants for R3-36 at 7LPM

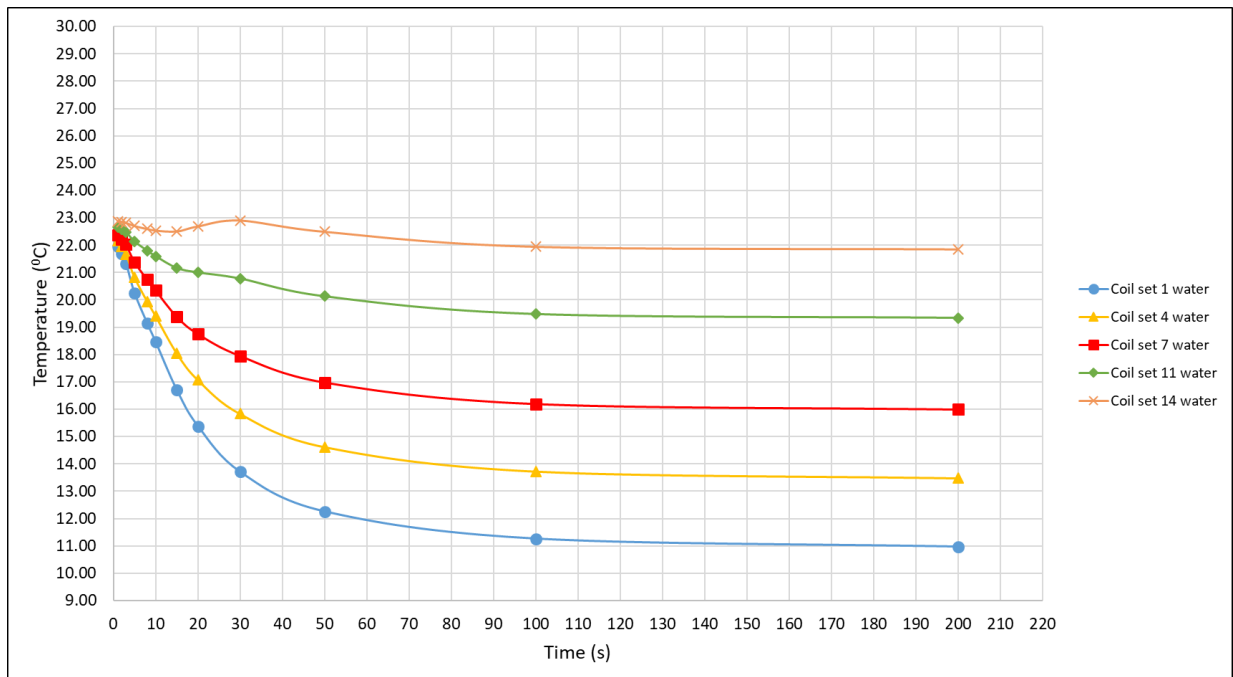


Figure J10: Estimated coil set water temperature profiles at different time instants for R3-36 at 7LPM

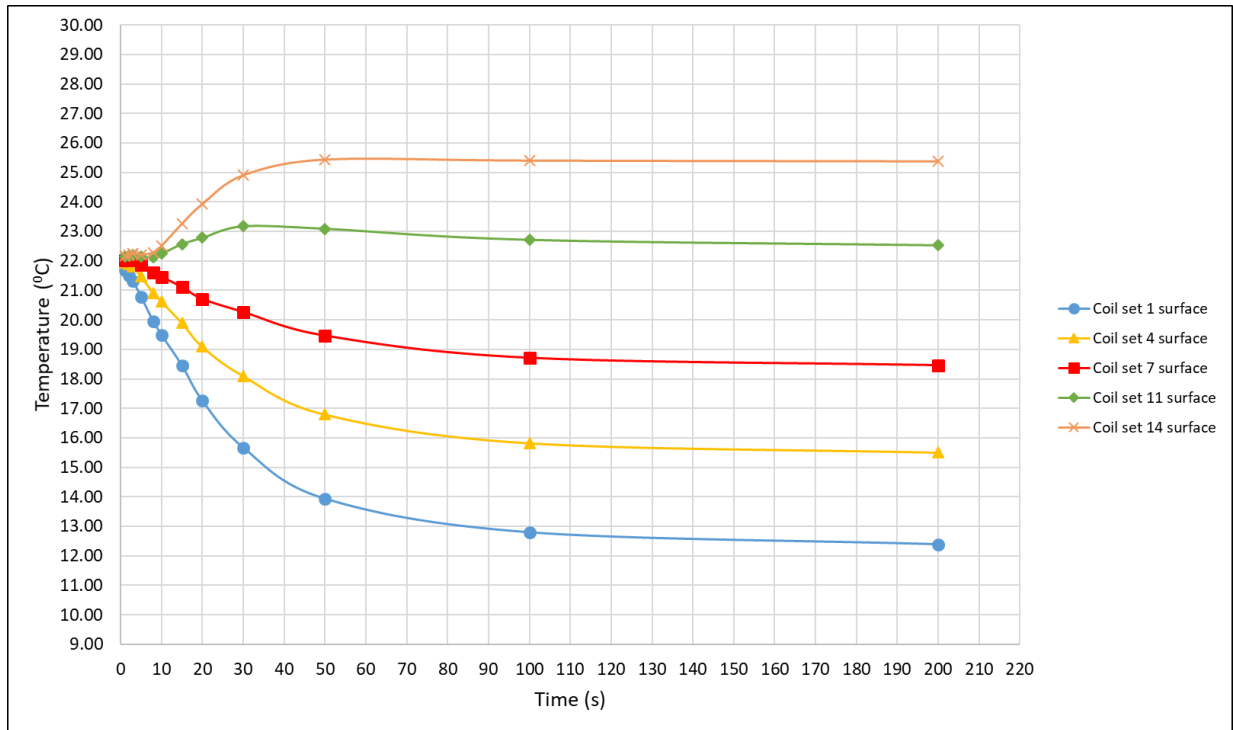


Figure J11: Coil set surface temperature profiles at different time instants for R3-36 at 5.5LPM

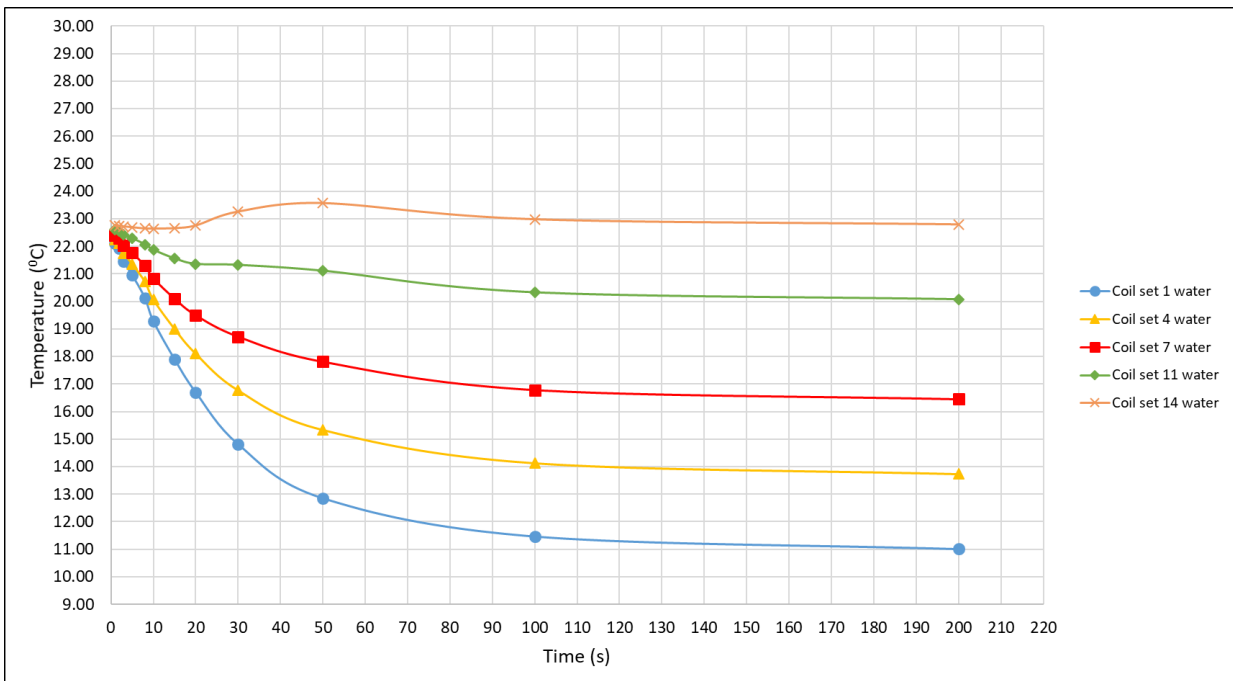


Figure J12: Estimated coil set water temperature profiles at different time instants for R3-36 at 5.5LPM

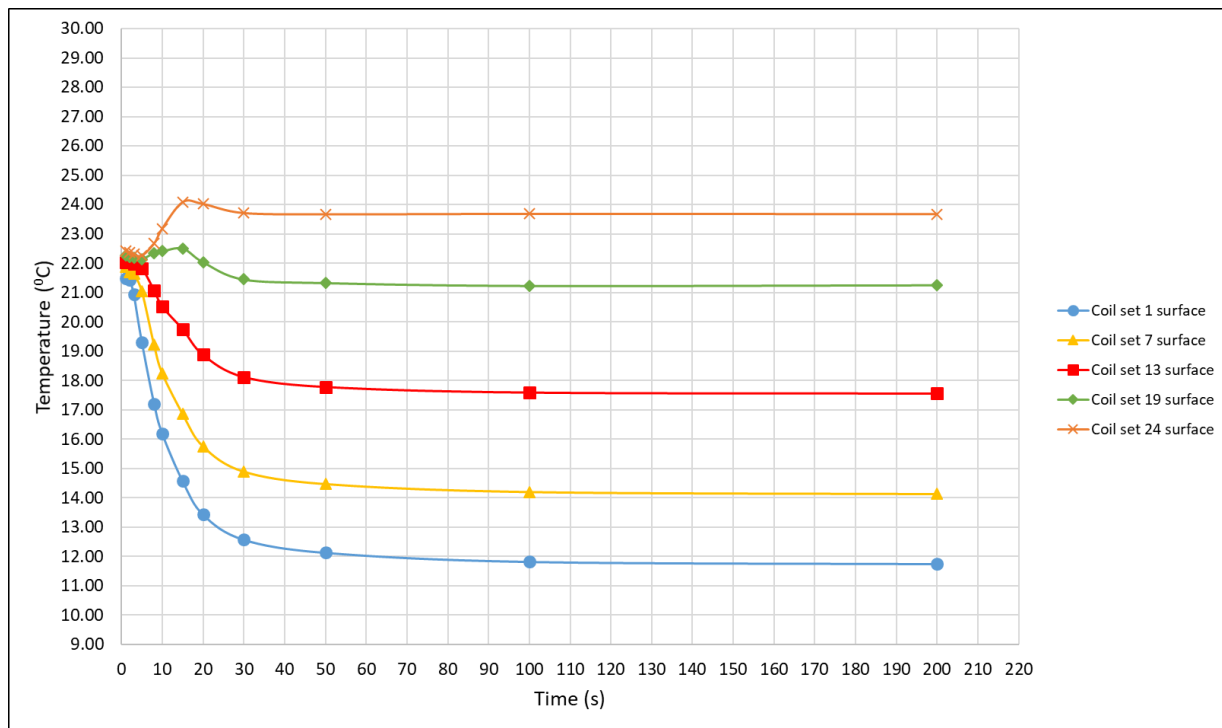


Figure J13: Coil set surface temperature profiles at different time instants for R3-60 at 14LPM

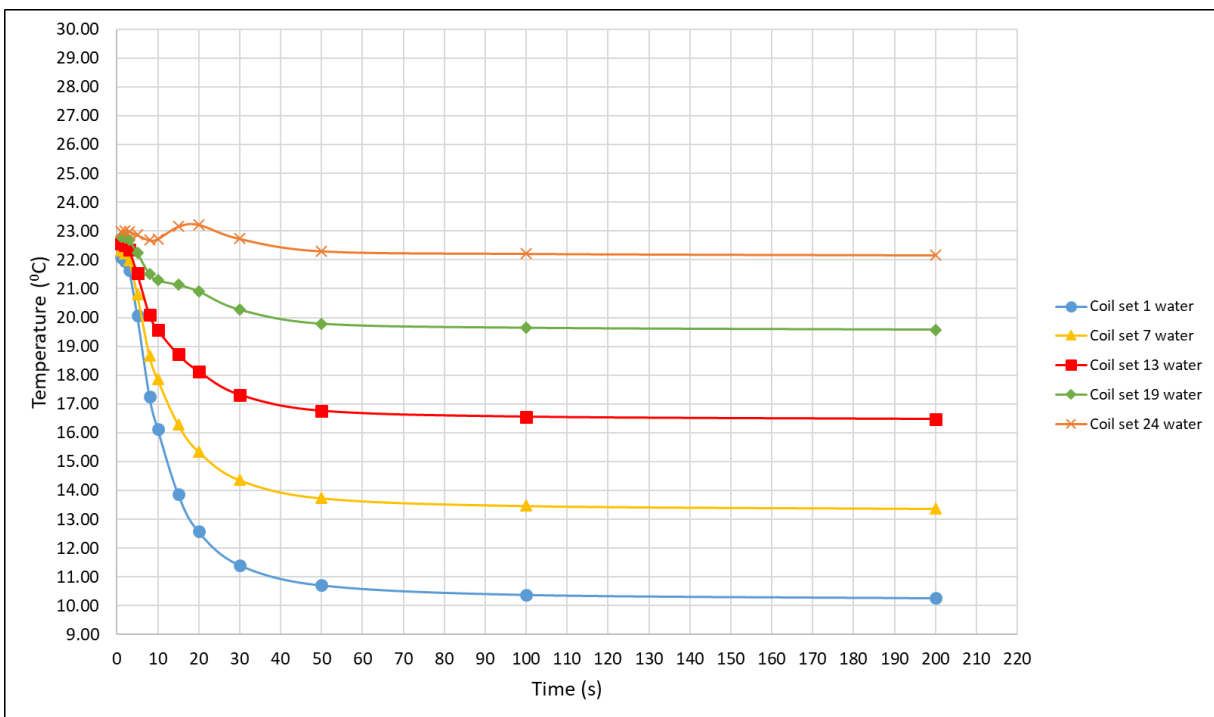


Figure J14: Estimated coil set water temperature profiles at different time instants for R3-60 at 14LPM

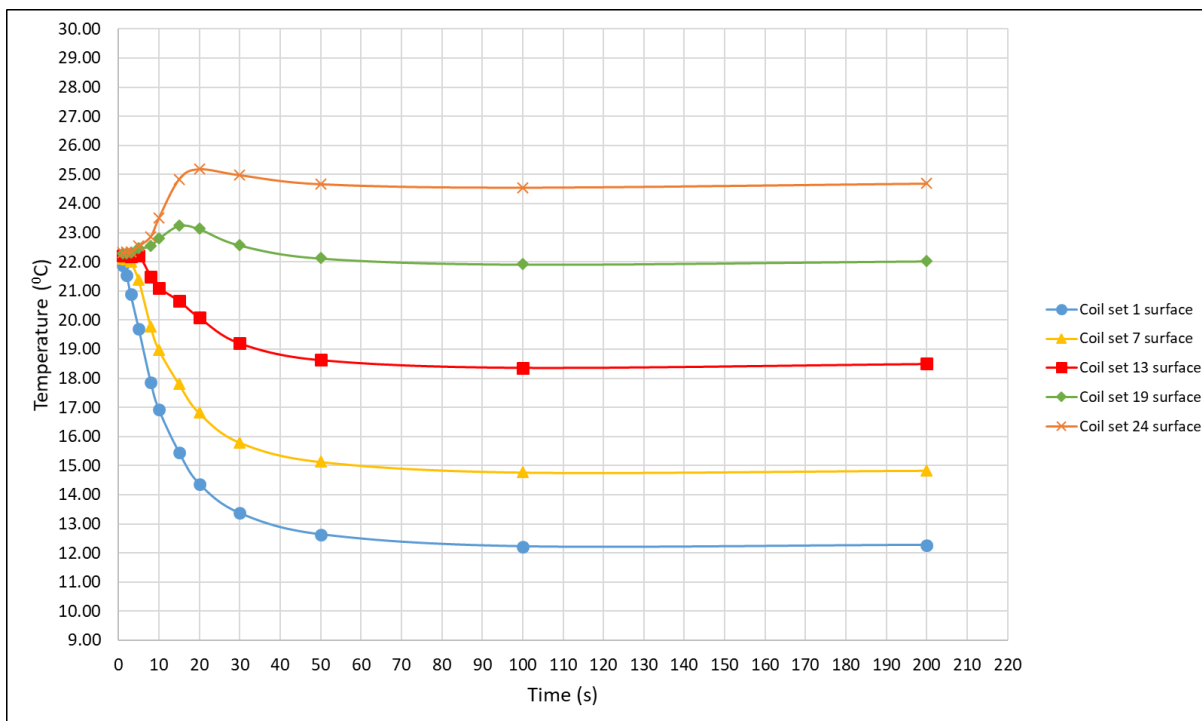


Figure J15: Coil set surface temperature profiles at different time instants for R3-60 at 12LPM

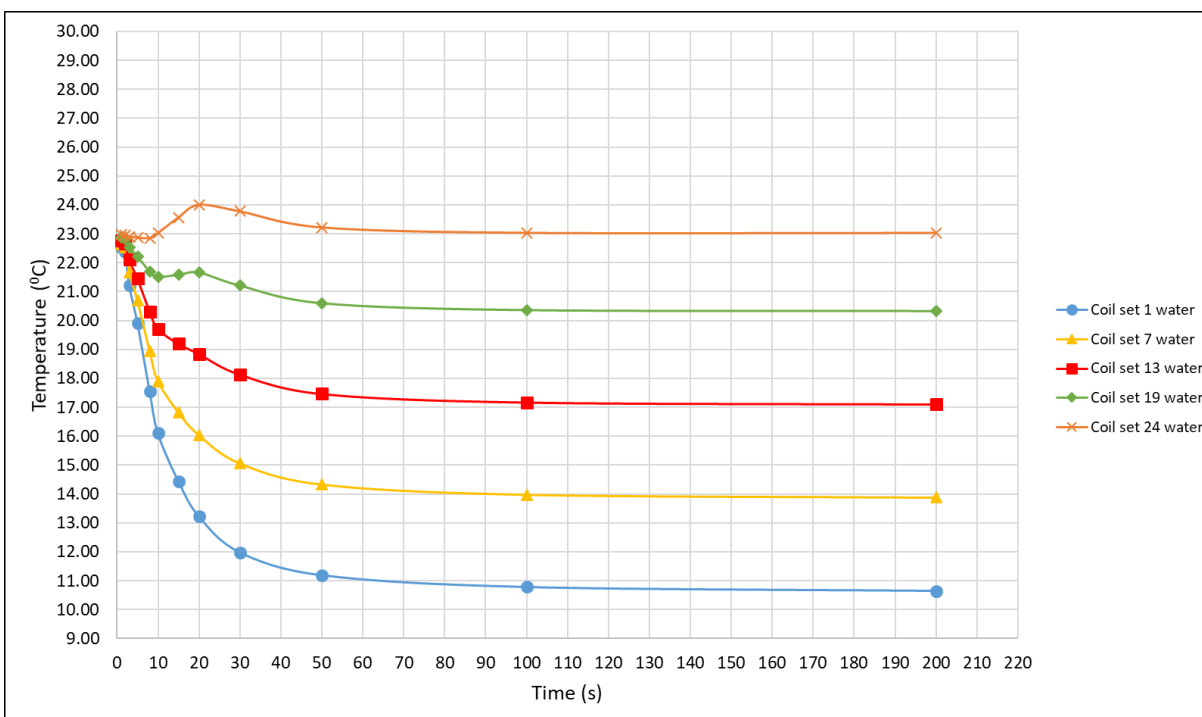


Figure J16: Estimated coil set water temperature profiles at different time instants for R3-60 at 12LPM

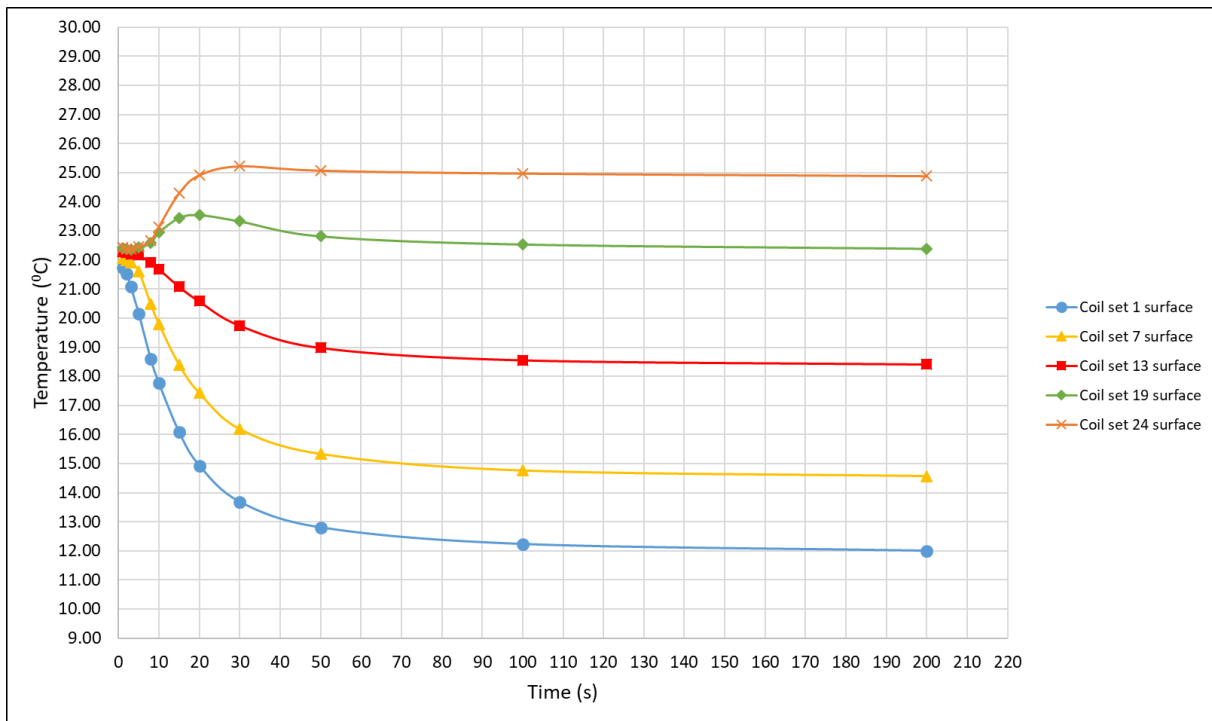


Figure J17: Coil set surface temperature profiles at different time instants for R3-60 at 10LPM

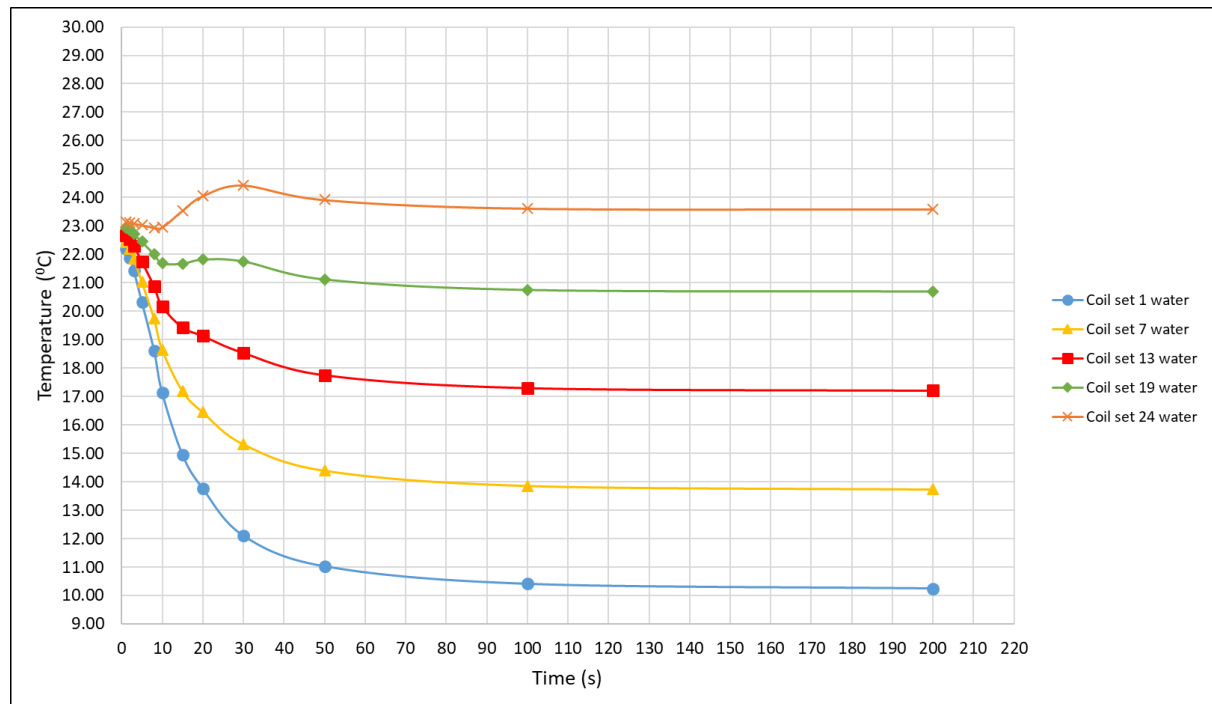


Figure J18: Estimated coil set water temperature profiles at different time instants for R3-60 at 10LPM

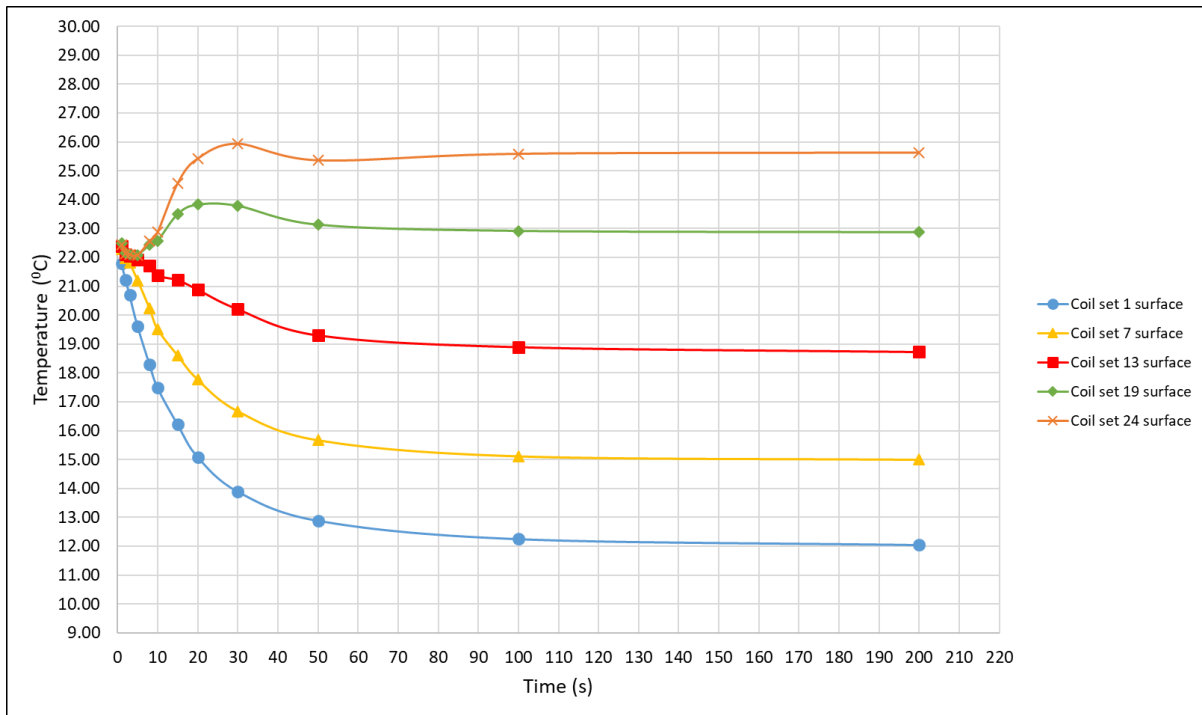


Figure J19: Coil set surface temperature profiles at different time instants for R3-60 at 9LPM

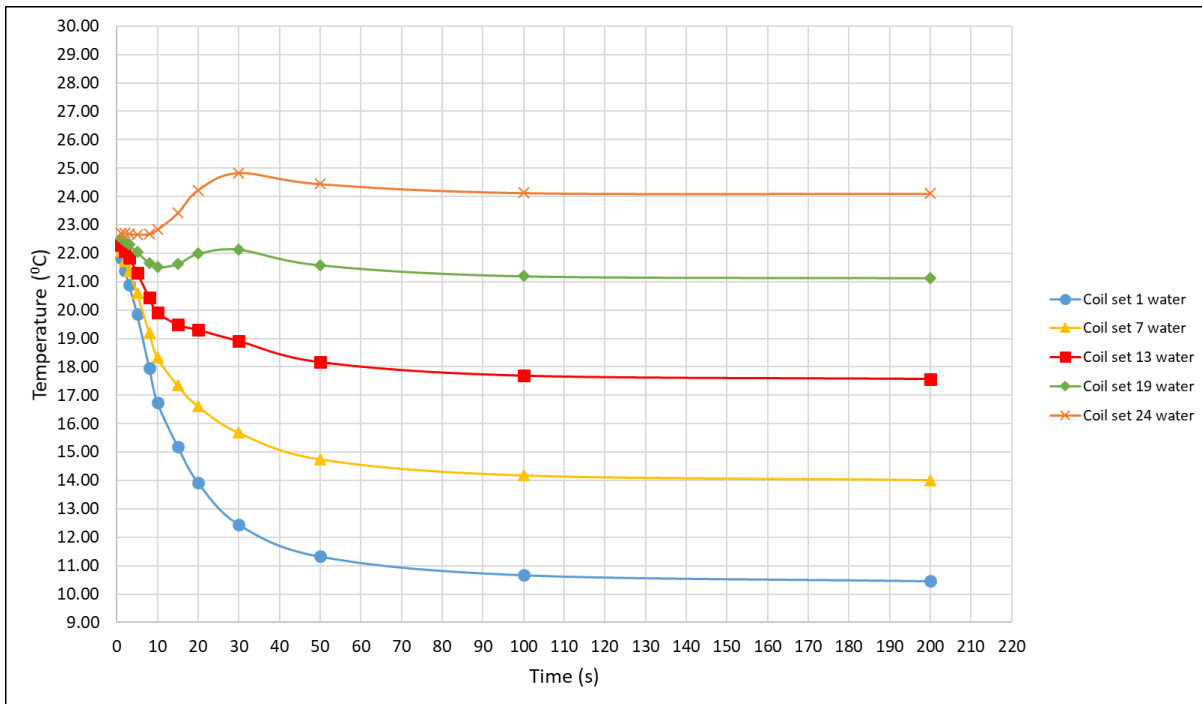


Figure J20: Estimated coil set water temperature profiles at different time instants for R3-60 at 9LPM

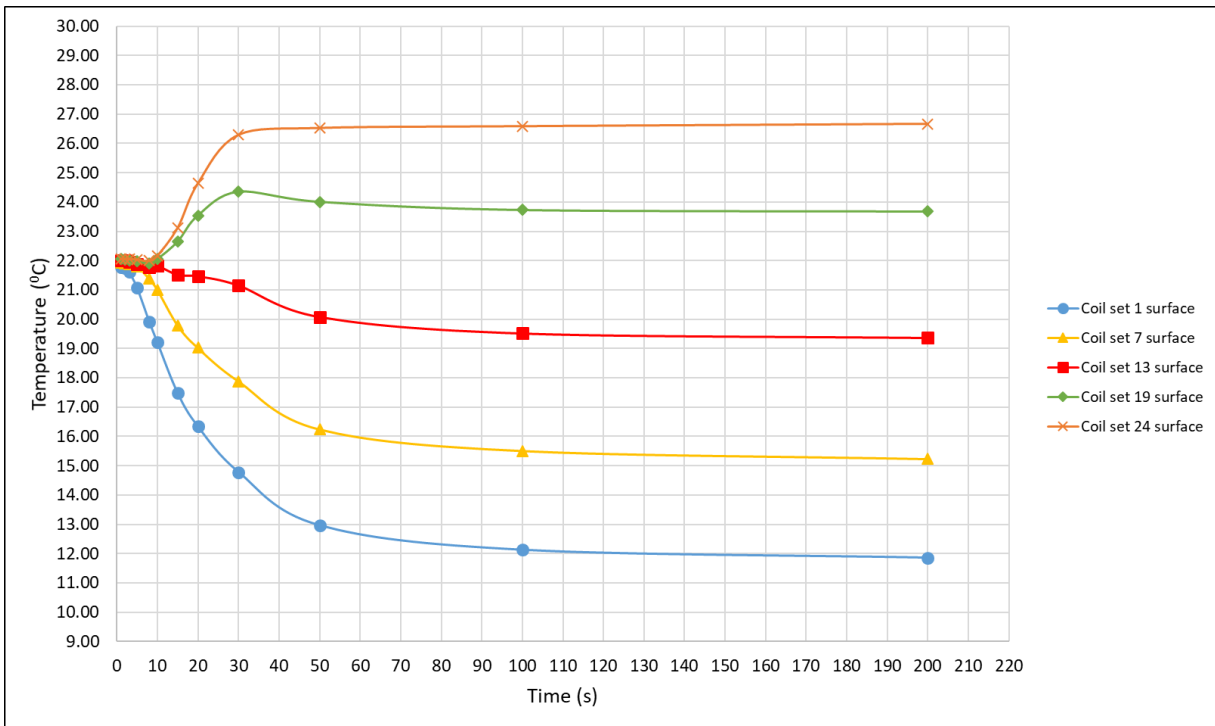


Figure J21: Coil set surface temperature profiles at different time instants for R3-60 at 7LPM

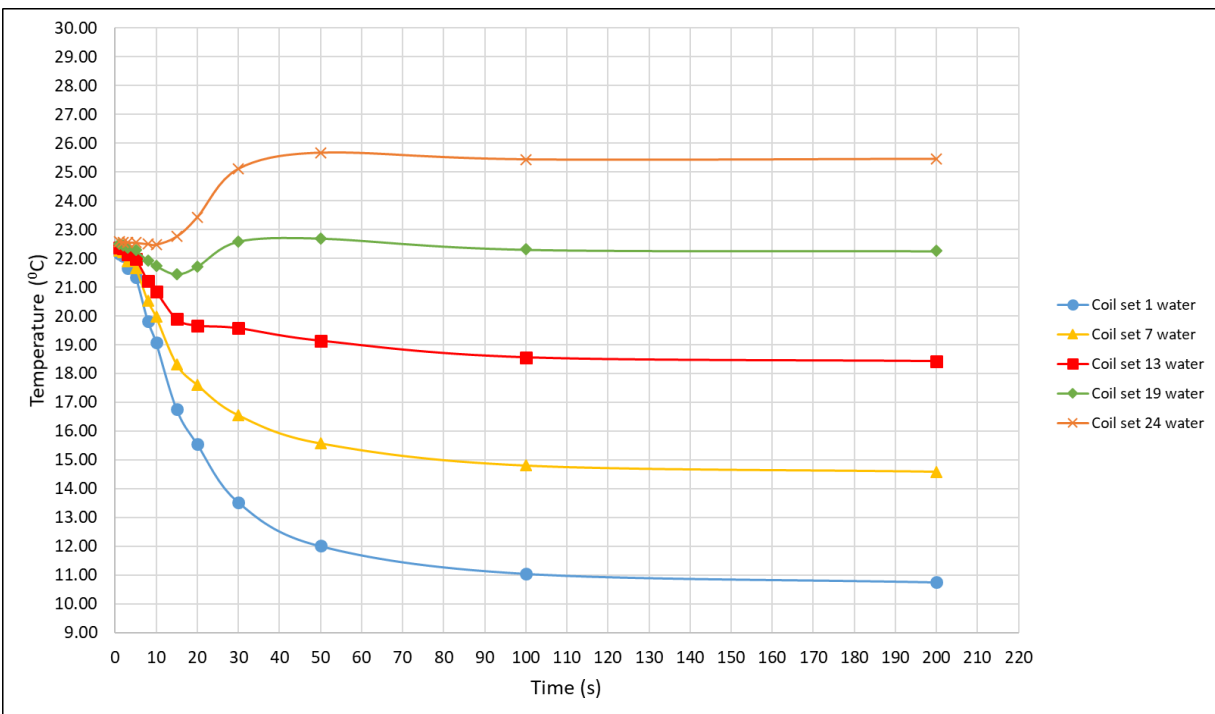


Figure J22: Estimated coil set water temperature profiles at different time instants for R3-60 at 7LPM

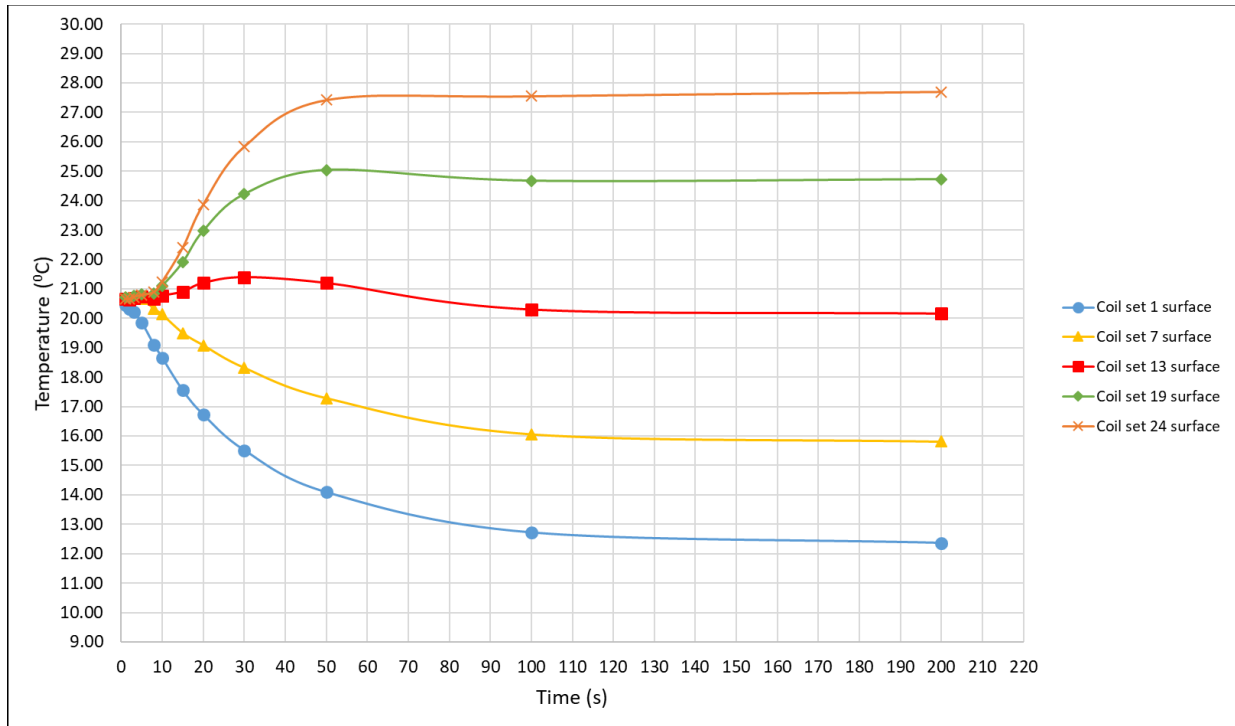


Figure J23: Coil set surface temperature profiles at different time instants for R3-60 at 5.5LPM

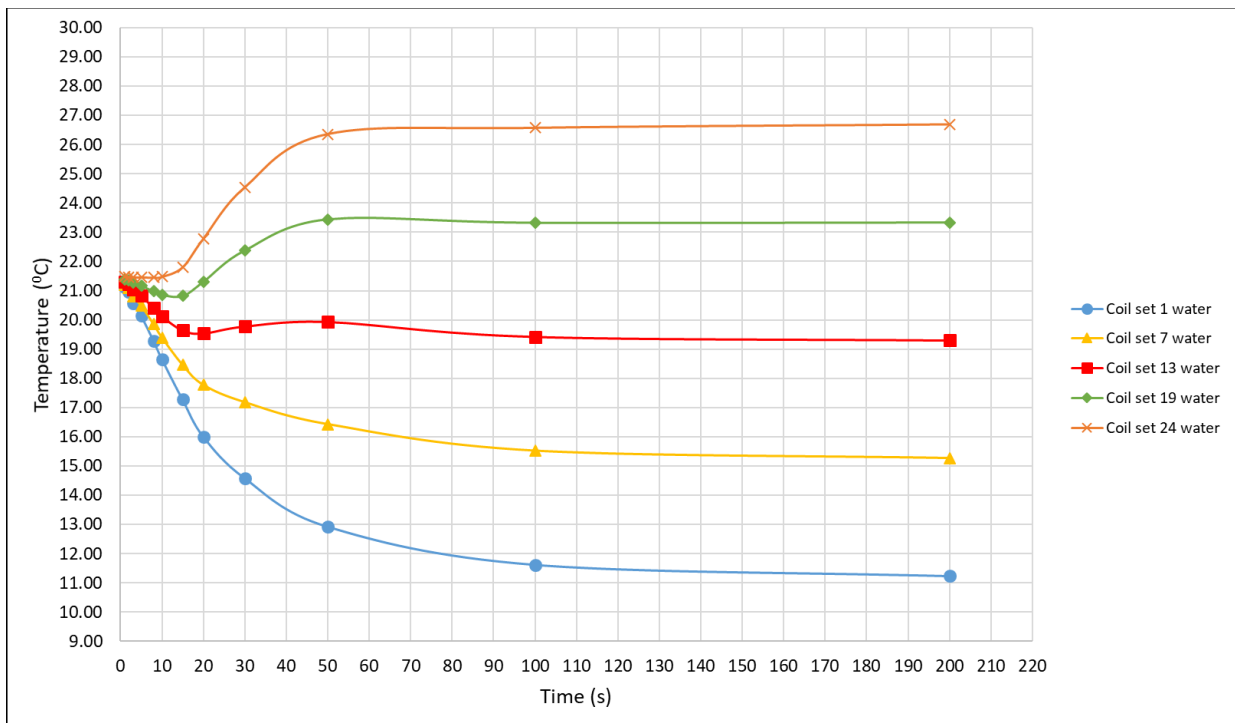


Figure J24: Estimated coil set water temperature profiles at different time instants for R3-60 at 5.5LPM

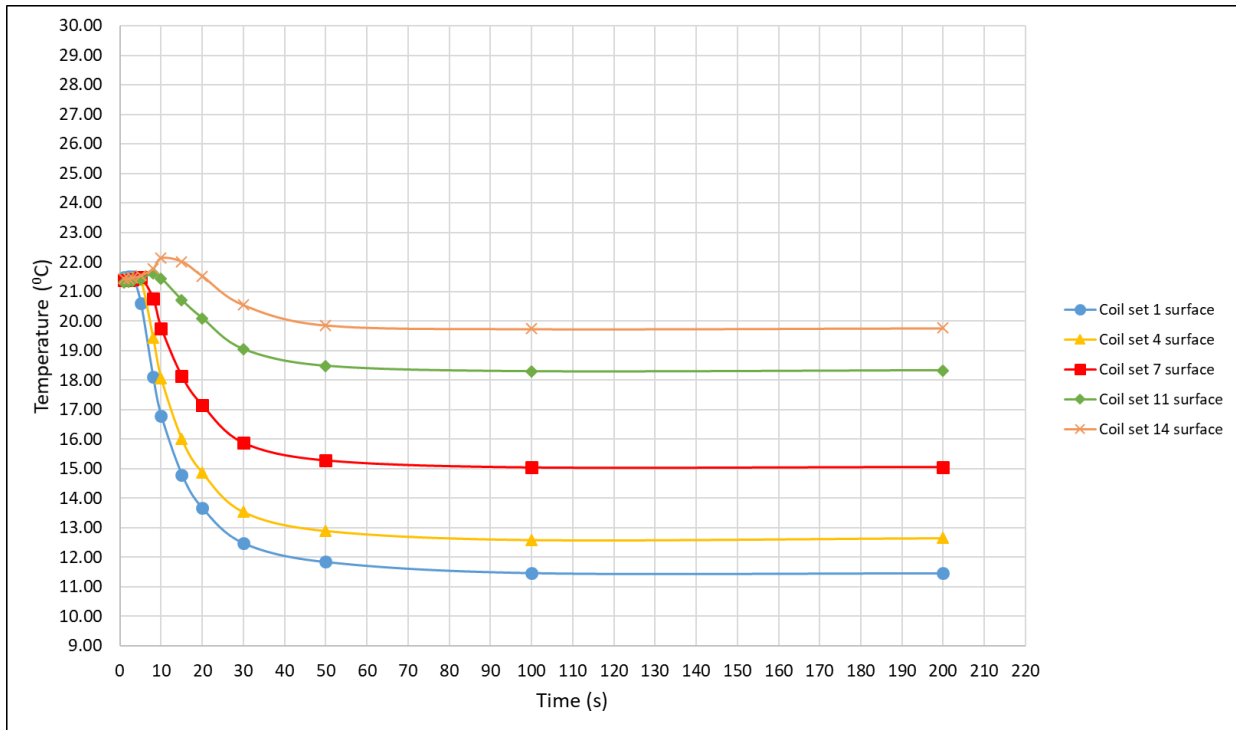


Figure J25: Coil set surface temperature profiles at different time instants for R4-36 at 14LPM

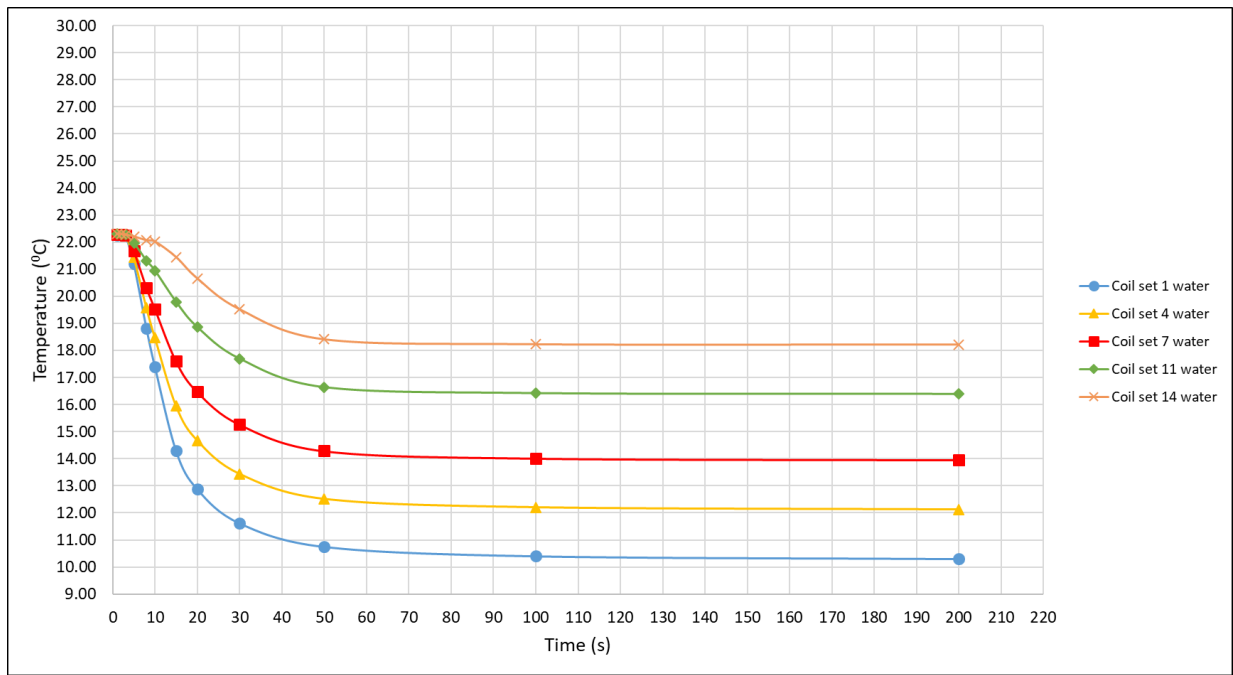


Figure J26: Estimated coil set water temperature profiles at different time instants for R4-36 at 14LPM

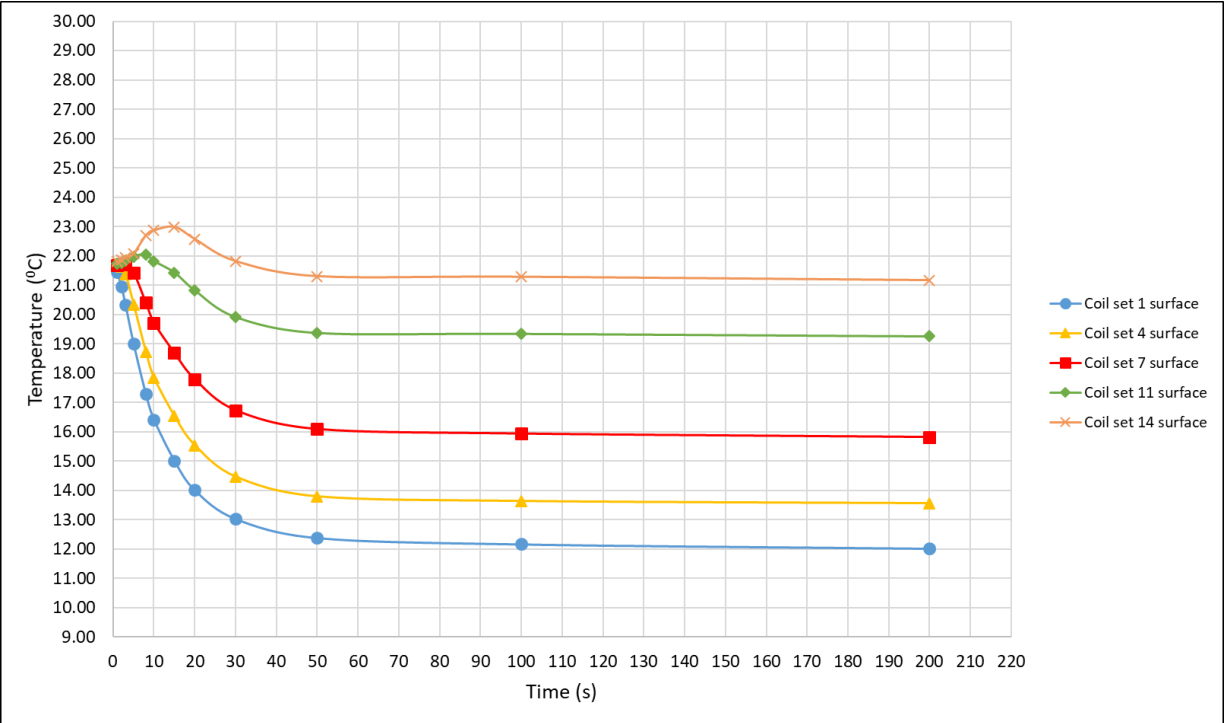


Figure J27: Coil set surface temperature profiles at different time instants for R4-36 at 12LPM

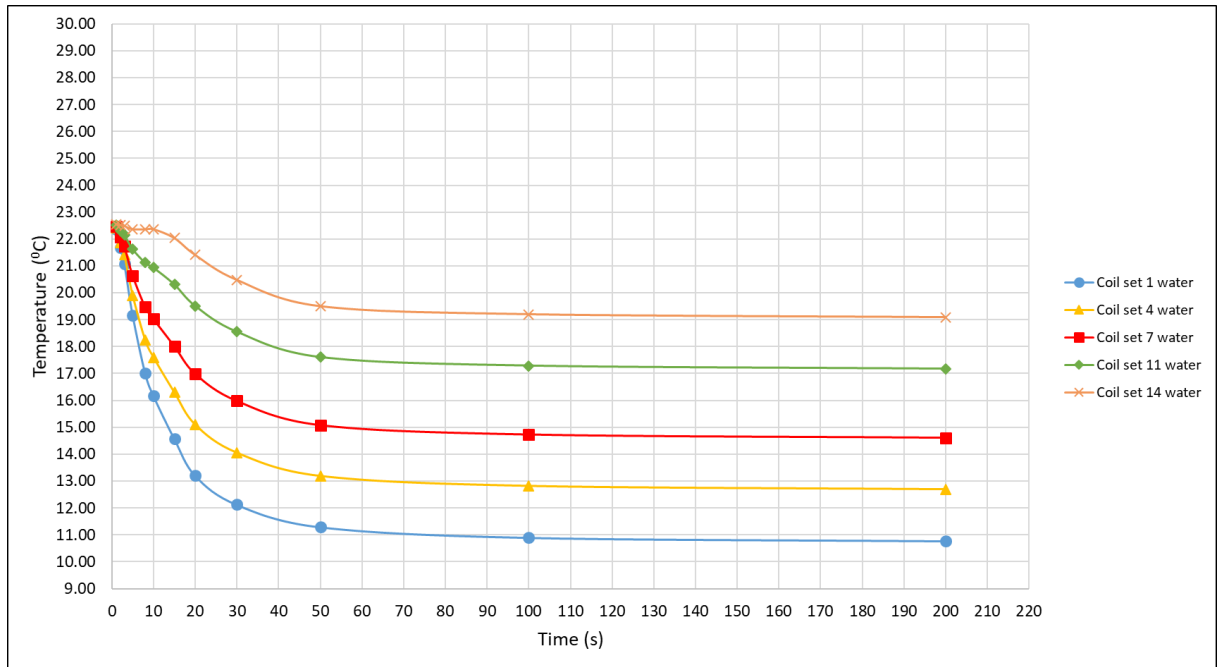


Figure J28: Estimated coil set water temperature profiles at different time instants for R4-36 at 12LPM

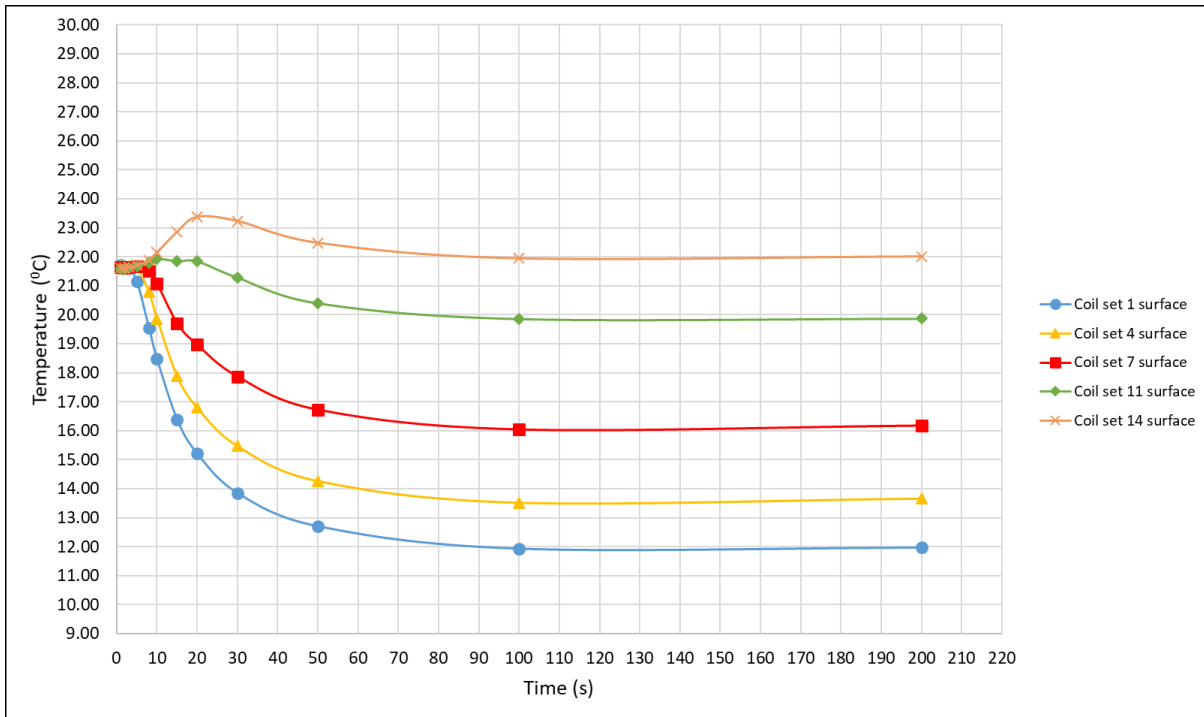


Figure J29: Coil set surface temperature profiles at different time instants for R4-36 at 10LPM

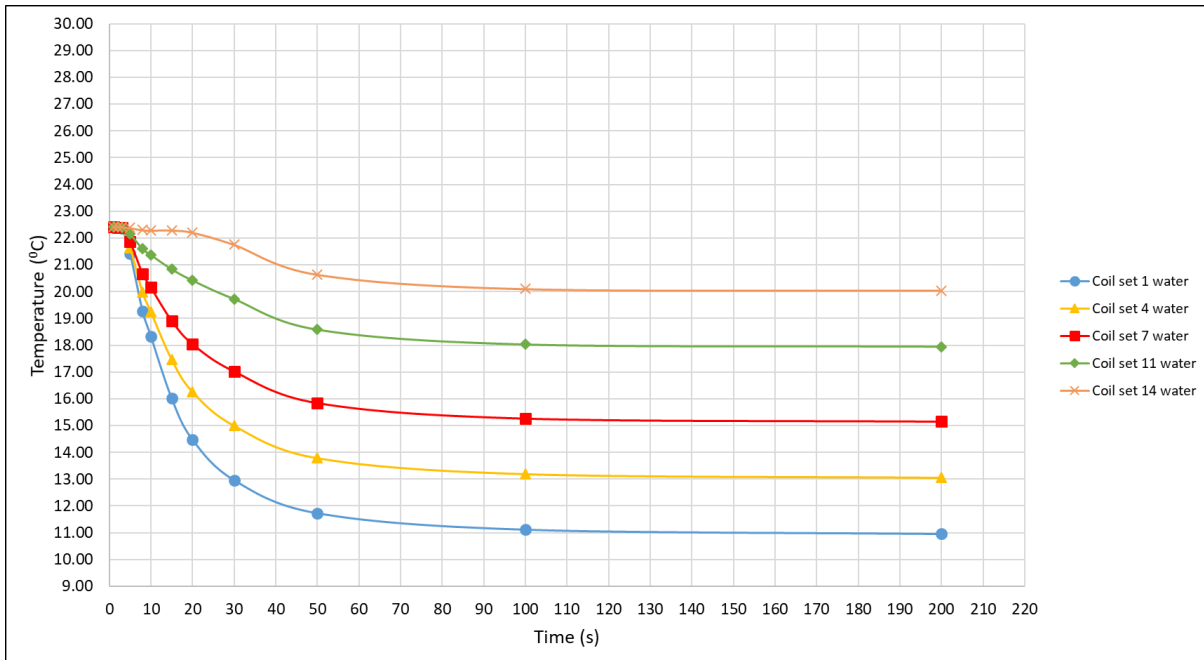


Figure J30: Estimated coil set water temperature profiles at different time instants for R4-36 at 10LPM

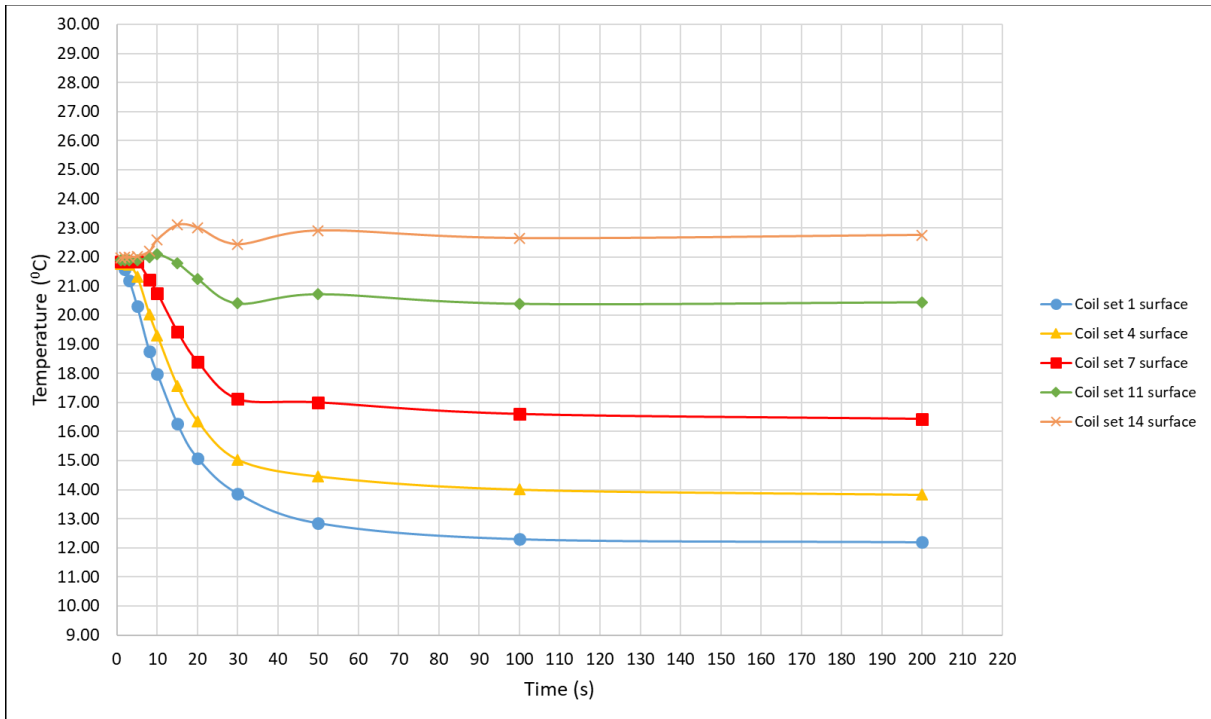


Figure J31: Coil set surface temperature profiles at different time instants for R4-36 at 9LPM

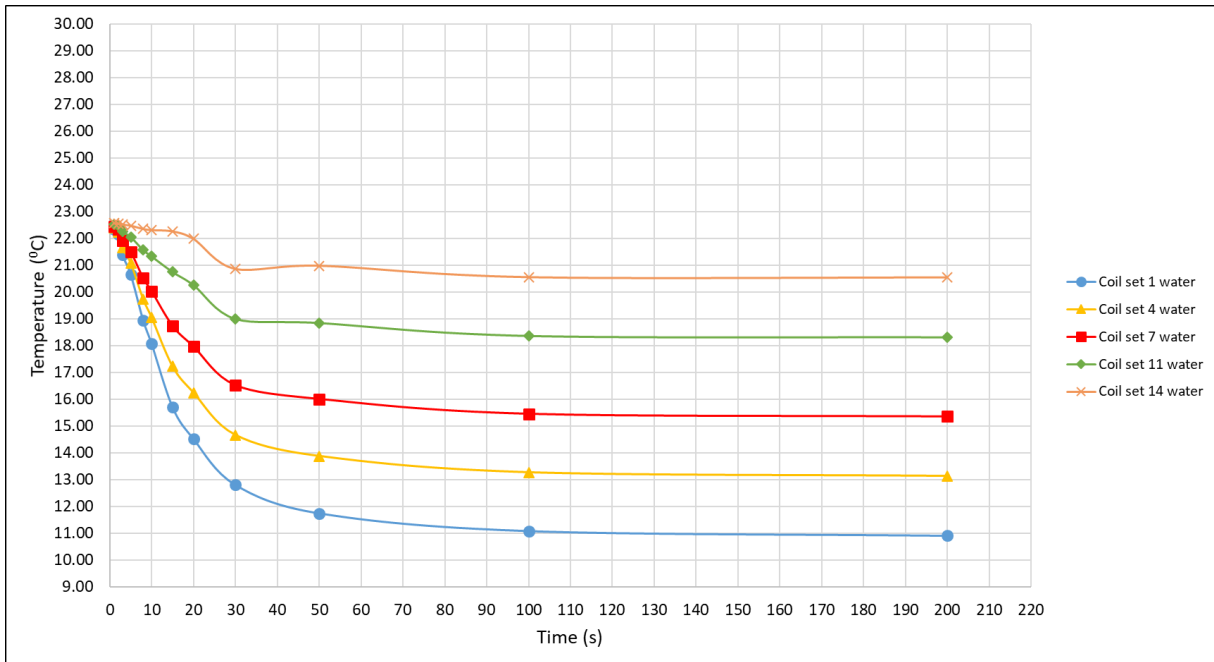


Figure J32: Estimated coil set water temperature profiles at different time instants for R4-36 at 9LPM

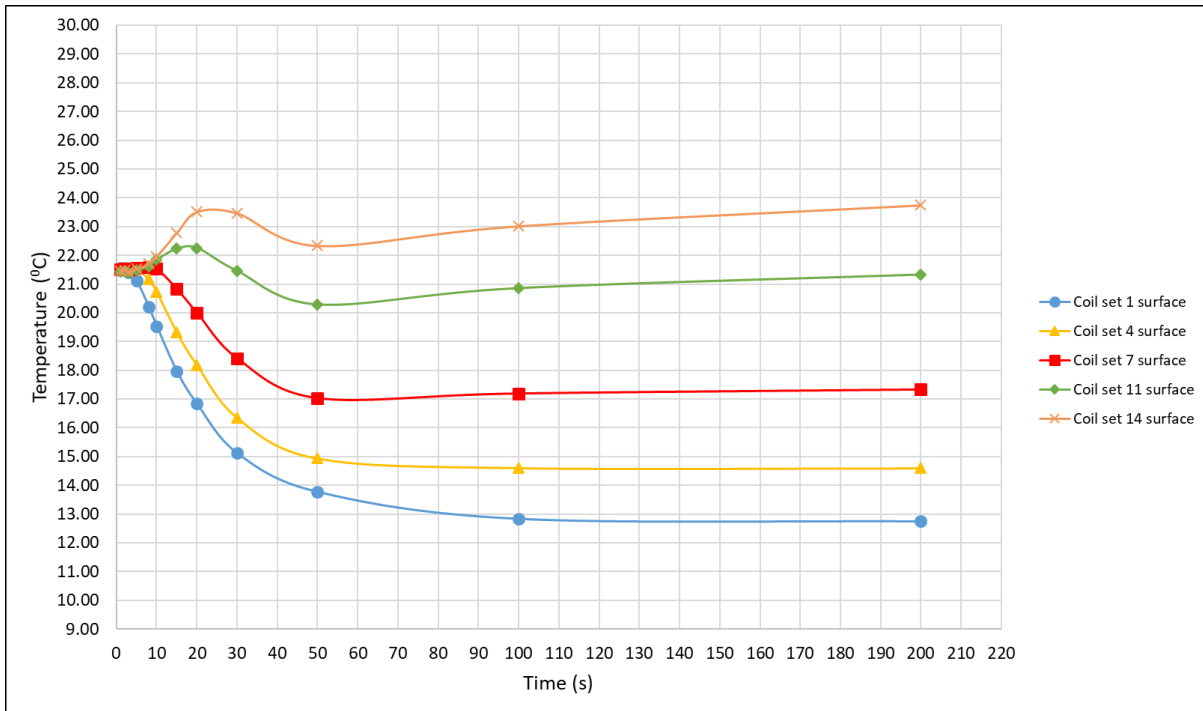


Figure J33: Coil set surface temperature profiles at different time instants for R4-36 at 7LPM

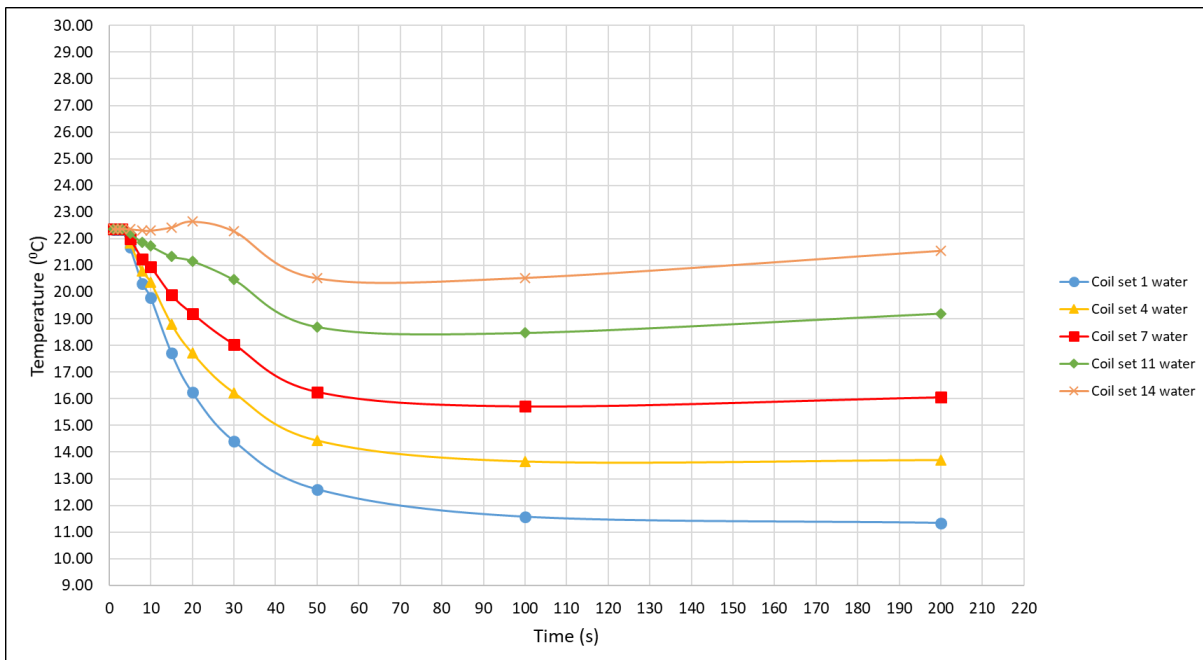


Figure J34: Estimated coil set water temperature profiles at different time instants for R4-36 at 7LPM

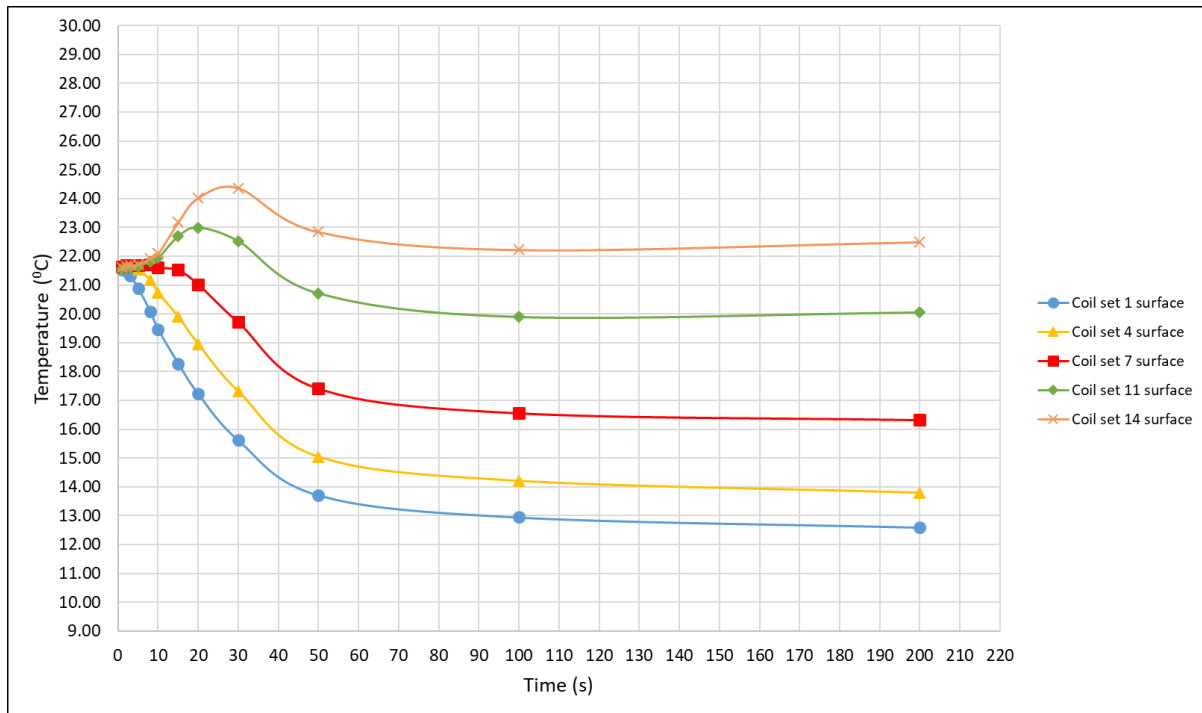


Figure J35: Coil set surface temperature profiles at different time instants for R4-36 at 5.5LPM

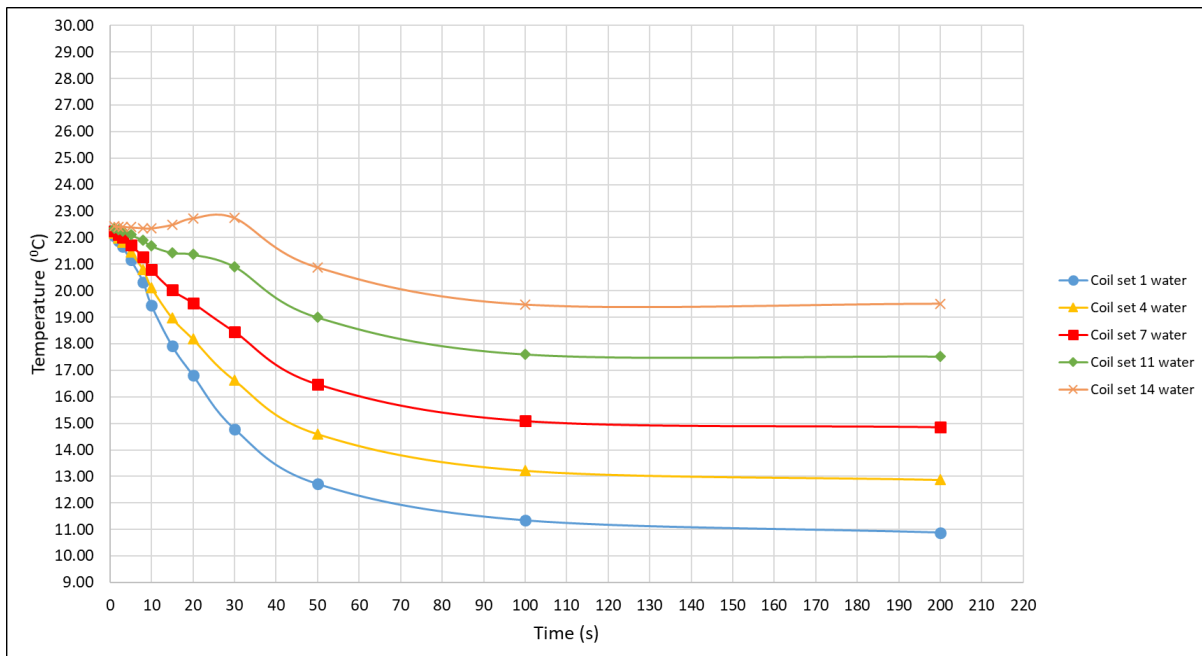


Figure J36: Estimated coil set water temperature profiles at different time instants for R4-36 at 5.5LPM

Appendix K: MATLAB Script for Biot Number and Convection Coefficients Estimation

```

clear
density = 0;          % declaring density variable. FIXED VALUE
Cp = 0;               % declaring specific heat variable. FIXED VALUE
mew = 0;              % declaring viscosity variable. FIXED VALUE
k = 0;                % declaring fluid conductivity variable. FIXED VALUE
Pr = 0;               % declaring Prandtl number variable. FIXED VALUE
coilVel = 0;          % declaring coil velocity. FIXED VALUE
REd = 0;              % declaring reynolds number variable. FIXED VALUE
De = 0;               % declaring dean's number. FIXED VALUE
volume = 0;           % declaring volume for Biot Number. FIXED VALUE
sArea = 0;            % declaring surface area for Biot Number. FIXED VALUE

flowrateLPM = 5.57;   % LPM. USER INPUT REQUIRED
aOD = 0.00794;        % actual OD width of single coil(m). USER INPUT NEEDED WHEN PIPE CHANGED
bOD = 0.01271;        % actual OD length of single coil(m). USER INPUT NEEDED WHEN PIPE CHANGED
D6 = 0.12044;         % outermost diameter of pipe (m). USER INPUT NEEDED WHEN PIPE CHANGED
Lcircum = 0.344;      % circumference of pipe for convection HT. (m). USER INPUT NEEDED IF PIPE CHANGED
thickness = 0.00152;  % thickness of outer coil wall. FIXED AND WON'T CHANGE
a = aOD-(2*thickness); % calculated ID width of single coil (m)
b = bOD-(2*thickness); % calculated ID height of single coil (m)
dh = (2*a*b)/(a+b);   % calculated hydraulic diameter
D = D6-aOD;           % calculated Nominal OD of pipe
kCOPPER = 401;        % thermal conductivity of COPPER

% NOTES: A = Tfluid in CELSIUS
%         B = Tfluid in KELVIN
%         C = Tsurface in CELSIUS
%         E = Tsurface in KELVIN
%         h = CONVECTION COEFFICIENT

% FLUID TEMP in CELSIUS. CHANGE AS NEEDED
A = [10.21 10.87 11.54 12.20 12.87 13.53 14.20 14.86 15.53 16.19 16.86 17.52 18.19 18.85 19.52 20.18];
B = A + 273.15;       % FLUID TEMP IN KELVIN

% SURFACE TEMP IN CELSIUS. CHANGE AS NEEDED
C = [10.21 12.60 12.49 13.27 13.80 14.38 15.43 16.32 17.22 18.06 18.90 20.06 20.82 21.59 22.49 20.18];
E = C + 273.15;       % SURFACE TEMP IN KELVIN

countelements = numel(A); % total elements in set
totalCount = countelements - 2; % total energy readings needed

hLAM = zeros(countelements,1); % Array of all LAMINAR convection coefficients
qLAM = zeros(countelements,1); % Array of TOTAL LAMINAR convective heat transfer for ENTIRE COILSET
BiLAM = zeros(countelements,1); % Array of all LAMINAR Biot Numbers

hTURB = zeros(countelements,1); % Array of all TURBULENT convection coefficients
qTURB = zeros(countelements,1); % Array of TOTAL TURBULENT convective heat transfer for ENTIRE COILSET
BiTURB = zeros(countelements,1); % Array of all TURBULENT Biot Numbers

totalconvQ = zeros(countelements,1); % Array of LAMINAR and TURBULENT qConv and Biot numbers

% INTERPOLATING DENSITY, Cp, VISCOSITY, CONDUCTIVITY and PRANDTL NUMBER
for i=2:(countelements-1)
    if (B(i)>=275) && (B(i)<280)
        density = 1/(0.001+((0.001-0.001)*((B(i)-275)/(280-275)))); % kg/m3
        Cp = 4.211+((4.198-4.211)*((B(i)-275)/(280-275))); % kJ/kg.K
        mew = 0.001652+((0.001422-0.001652)*((B(i)-275)/(280-275))); % N.s/m2
        k = 0.574+((0.582-0.574)*((B(i)-275)/(280-275))); % W/m.K
        Pr = 12.22+((10.26-12.22)*((B(i)-275)/(280-275))); % DimensionLess
        volume = a*b*Lcircum; % Volume for Biot Number
        sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
        coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
        REd = (density*coilVel*dh)/mew; % calculating Reynolds number
        De = REd*(sqrt(dh/D)); % calculating Dean's number
        hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
        hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating turbulent h (W/m2K)
        qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
        qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
        BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number
        BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
        totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB
    end
end

```

```

elseif (B(i)>=280) && (B(i)<285)
    density = 1/(0.001+((0.001-0.001)*((B(i)-280)/(285-280)))); % kg/m3
    Cp = 4.198+((4.189-4.198)*((B(i)-280)/(285-280))); % kJ/kg.K

    mew = 0.001422+((0.001225-0.001422)*((B(i)-280)/(285-280))); % N.s/m2
    k = 0.582+((0.59-0.582)*((B(i)-280)/(285-280))); % W/m.K
    Pr = 10.26+((8.81-10.26)*((B(i)-280)/(285-280))); % DimensionLess
    volume = a*b*Lcircum; % Volume for Biot Number
    sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
    coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
    REd = (density*coilVel*dh)/mew; % calculating Reynolds number
    De = REd*(sqrt(dh/D)); % calculating Dean's number
    hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
    hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating TURBULENT h (W/m2K)

    qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
    qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
    BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number
    BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
    totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB

elseif (B(i)>=285) && (B(i)<290)
    density = 1/(0.001+((0.001001-0.001)*((B(i)-285)/(290-285)))); % kg/m3
    Cp = 4.189+((4.184-4.189)*((B(i)-285)/(290-285))); % kJ/kg.K
    mew = 0.001225+((0.001080-0.001225)*((B(i)-285)/(290-285))); % N.s/m2
    k = 0.59+((0.598-0.59)*((B(i)-285)/(290-285))); % W/m.K
    Pr = 8.81+((7.56-8.81)*((B(i)-285)/(290-285))); % DimensionLess
    volume = a*b*Lcircum; % Volume for Biot Number
    sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
    coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
    REd = (density*coilVel*dh)/mew; % calculating Reynolds number
    De = REd*(sqrt(dh/D)); % calculating Dean's number
    hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
    hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating TURBULENT h (W/m2K)

    qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
    qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
    BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number
    BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
    totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB

elseif (B(i)>=290) && (B(i)<295)
    density = 1/(0.001001+((0.001002-0.001001)*((B(i)-290)/(295-290)))); % kg/m3
    Cp = 4.184+((4.181-4.184)*((B(i)-290)/(295-290))); % kJ/kg.K
    mew = 0.001080+((0.000959-0.001080)*((B(i)-290)/(295-290))); % N.s/m2
    k = 0.598+((0.606-0.598)*((B(i)-290)/(295-290))); % W/m.K
    Pr = 7.56+((6.62-7.56)*((B(i)-290)/(295-290))); % DimensionLess
    volume = a*b*Lcircum; % Volume for Biot Number
    sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
    coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
    REd = (density*coilVel*dh)/mew; % calculating Reynolds number
    De = REd*(sqrt(dh/D)); % calculating Dean's number
    hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
    hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating TURBULENT h (W/m2K)

    qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
    qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
    BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number
    BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
    totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB

elseif (B(i)>=295) && (B(i)<300)
    density = 1/(0.001002+((0.001003-0.001002)*((B(i)-295)/(300-295)))); % kg/m3
    Cp = 4.181+((4.179-4.181)*((B(i)-295)/(300-295))); % kJ/kg.K
    mew = 0.000959+((0.000855-0.000959)*((B(i)-295)/(300-295))); % N.s/m2
    k = 0.606+((0.613-0.606)*((B(i)-295)/(300-295))); % W/m.K
    Pr = 6.62+((5.83-6.62)*((B(i)-295)/(300-295))); % DimensionLess
    volume = a*b*Lcircum; % Volume for Biot Number
    sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
    coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
    REd = (density*coilVel*dh)/mew; % calculating Reynolds number
    De = REd*(sqrt(dh/D)); % calculating Dean's number
    hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
    hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating TURBULENT h (W/m2K)

    qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
    qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
    BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number

```

```

BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB

elseif (B(i)>=300) && (B(i)<305)
density = 1/(0.001003+((0.001005-0.001003)*((B(i)-300)/(305-300)))); % kg/m3
Cp = 4.179+((4.178-4.179)*((B(i)-300)/(305-300))); % kJ/kg.K
mew = 0.000855+((0.000769-0.000855)*((B(i)-300)/(305-300))); % N.s/m2
k = 0.613+((0.620-0.613)*((B(i)-300)/(305-300))); % W/m.K
Pr = 5.83+((5.20-5.83)*((B(i)-300)/(305-300))); % DimensionLess

volume = a*b*Lcircum; % Volume for Biot Number
sArea = 2*Lcircum*(a+b); % Surface Area for Biot Number
coilVel = ((flowrateLPM/4)/60000)/(a*b); % calculating Velocity of each coil m/s
REd = (density*coilVel*dh)/mew; % calculating Reynolds number
De = REd*(sqrt(dh/D)); % calculating Dean's number
hLAM(i) = ((0.913*(power(De,0.476))*(power(Pr,0.2)))*k)/dh; % calculating LAMINAR h (W/m2K)
hTURB(i) = ((0.023*(power(REd,0.8))*(power(Pr,0.4))*(1+(3.4*(dh/D))))*k)/dh; % calculating TURBULENT h (W/m2K)

qLAM(i) = (4 * hLAM(i) * sArea * (E(i) - B(i)))/1000; % calculating LAMINAR Qconv for coilset (kW)
qTURB(i) = (4 * hTURB(i) * sArea * (E(i) - B(i)))/1000; % calculating TURBULENT Qconv for coilset (kW)
BiLAM(i) = (hLAM(i)/kCOPPER)*(volume/sArea); % calculating LAMINAR Biot Number
BiTURB(i) = (hTURB(i)/kCOPPER)*(volume/sArea); % calculating TURBULENT Biot Number
totalconvQ = horzcat(qLAM,BiLAM,qTURB,BiTURB); % final array of calculated qCONV and Biot numbers both LAM and TURB
end
end

```


Appendix L: MATLAB Script for Flow Energy Rate Calculations

```

clear
flowrateLPM = 5.57; % LPM

% NOTES: A = Tfluid in CELSIUS
%         B = Tfluid in KELVIN

A = [10.21 10.87 11.54 12.20 12.87 13.53 14.20 14.86 15.53 16.19 16.86 17.52 18.19 18.85 19.52 20.18];
B = A + 273.15; % in Kelvin
countelements = numel(A); % total elements in set
totalCount = countelements - 2; % total energy readings needed
inputQ = zeros(countelements,1); % storing computed heat input kW
outputQ = zeros(countelements,1); % storing computed heat output kW
ioQ = zeros(countelements,1); % concatenated final array
deltaQ = zeros(countelements,1); % storing computed heat gain kW
Cp = 0; % declaring specific heat variable
density = 0; % declaring density variable

for i=2:(countelements-1)
    if (B(i)>=275) && (B(i)<280)
        Cp = 4.211+((4.198-4.211)*((B(i)-275)/(280-275))); % kJ/kg.K
        density = 1/((0.001+((0.001-0.001)*((B(i)-275)/(280-275)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    elseif (B(i)>=280) && (B(i)<285)
        Cp = 4.198+((4.189-4.198)*((B(i)-280)/(285-280))); % kJ/kg.K
        density = 1/((0.001+((0.001-0.001)*((B(i)-280)/(285-280)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    elseif (B(i)>=285) && (B(i)<290)
        Cp = 4.189+((4.184-4.189)*((B(i)-285)/(290-285))); % kJ/kg.K
        density = 1/((0.001+((0.001001-0.001)*((B(i)-285)/(290-285)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    elseif (B(i)>=290) && (B(i)<295)
        Cp = 4.184+((4.181-4.184)*((B(i)-290)/(295-290))); % kJ/kg.K
        density = 1/((0.001001+((0.001002-0.001001)*((B(i)-290)/(295-290)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    elseif (B(i)>=295) && (B(i)<300)
        Cp = 4.181+((4.179-4.181)*((B(i)-295)/(300-295))); % kJ/kg.K
        density = 1/((0.001002+((0.001003-0.001002)*((B(i)-295)/(300-295)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    elseif (B(i)>=300) && (B(i)<305)
        Cp = 4.179+((4.178-4.179)*((B(i)-300)/(305-300))); % kJ/kg.K
        density = 1/((0.001003+((0.001005-0.001003)*((B(i)-300)/(305-300)))); % kg/m3
        inputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i-1);
        outputQ(i) = ((flowrateLPM/60000)*density)*Cp*B(i);
        ioQ = horzcat(inputQ,outputQ);
        deltaQ(i) = outputQ(i) - inputQ(i);
    end
end
totaldeltaQ = sum(deltaQ);

```

Appendix L: MATLAB Script for Storage Energy Rate Calculations

```

clear

volumeCoilset = 0.000058651;          % fluid volume in each coilset m3. CHANGE AS NEEDED

                                      % WaterTempC = Fluid temperature in coil sets measured in
Celsius
WaterTempC = [10.13 10.97 11.80 12.64 13.48 14.32 15.15 15.99 16.83 17.67 18.50 19.34 20.18 21.02 21.85
22.69];
WaterTempK = WaterTempC + 273.15;      % Fluid temperature in coil sets measured in Kelvin

                                      % dTdt = dT/dt
dTdt = [-0.003 -0.003 -0.003 -0.003 -0.002 -0.002 -0.002 -0.002 -0.002 -0.002 -0.002 -0.001 -0.001 -0.001
-0.001 -0.001];

                                      % K/s or C/s
countelements = numel(WaterTempC);     % total elements in set
totalCount = countelements - 2;         % total energy readings needed
storageQ = zeros(countelements,1);     % storage in kW

Cp = 0;                                % declaring specific heat variable
density = 0;                            % declaring density variable

for i=2:(countelements-1)
    if (WaterTempK(i)>=275) && (WaterTempK(i)<280)
        Cp = 4.211+((4.198-4.211)*((WaterTempK(i)-275)/(280-275)));           % kJ/kg.K
        density = 1/(0.001+((0.001-0.001)*((WaterTempK(i)-275)/(280-275)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    elseif (WaterTempK(i)>=280) && (WaterTempK(i)<285)
        Cp = 4.198+((4.189-4.198)*((WaterTempK(i)-280)/(285-280)));           % kJ/kg.K
        density = 1/(0.001+((0.001-0.001)*((WaterTempK(i)-280)/(285-280)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    elseif (WaterTempK(i)>=285) && (WaterTempK(i)<290)
        Cp = 4.189+((4.184-4.189)*((WaterTempK(i)-285)/(290-285)));           % kJ/kg.K
        density = 1/(0.001+((0.001001-0.001)*((WaterTempK(i)-285)/(290-285)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    elseif (WaterTempK(i)>=290) && (WaterTempK(i)<295)
        Cp = 4.184+((4.181-4.184)*((WaterTempK(i)-290)/(295-290)));           % kJ/kg.K
        density = 1/(0.001001+((0.001002-0.001001)*((WaterTempK(i)-290)/(295-290)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    elseif (WaterTempK(i)>=295) && (WaterTempK(i)<300)
        Cp = 4.181+((4.179-4.181)*((WaterTempK(i)-295)/(300-295)));           % kJ/kg.K
        density = 1/(0.001002+((0.001003-0.001002)*((WaterTempK(i)-295)/(300-295)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    elseif (WaterTempK(i)>=300) && (WaterTempK(i)<305)
        Cp = 4.179+((4.178-4.179)*((WaterTempK(i)-300)/(305-300)));           % kJ/kg.K
        density = 1/(0.001003+((0.001005-0.001003)*((WaterTempK(i)-300)/(305-300)))); % kg/m3
        storageQ(i) = density*volumeCoilset*Cp*dTdt(i);                     % kW
    end
end

```

Appendix M: Energy Balance Tables at Coil Sets

Table M1: Coil Set Energy Balance for R3-36 at 14LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0064	0.0000	0.0064	0.0083	-0.0051	0.0031	0.0096	-0.0046	0.0049	0.1060	-0.1692	-0.0632
2	0.0128	0.0000	0.0128	0.0083	-0.0056	0.0027	0.0096	-0.0046	0.0049	0.1060	-0.1574	-0.0514
3	0.0064	0.0000	0.0064	0.0083	-0.0059	0.0024	0.0192	-0.0044	0.0148	0.1060	-0.1454	-0.0394
4	0.0064	0.0000	0.0064	0.0166	-0.0061	0.0104	0.0096	-0.0042	0.0054	0.1060	-0.1334	-0.0274
5	0.0064	0.0000	0.0064	0.0083	-0.0066	0.0017	0.0096	-0.0042	0.0054	0.1060	-0.1216	-0.0157
6	0.0128	0.0000	0.0128	0.0083	-0.0069	0.0014	0.0096	-0.0039	0.0057	0.1060	-0.1096	-0.0037
7	0.0064	0.0000	0.0064	0.0083	-0.0071	0.0012	0.0096	-0.0037	0.0059	0.1060	-0.0977	0.0083
8	0.0064	0.0000	0.0064	0.0083	-0.0076	0.0007	0.0192	-0.0037	0.0155	0.0963	-0.0859	0.0104
9	0.0064	0.0000	0.0064	0.0083	-0.0078	0.0005	0.0096	-0.0034	0.0062	0.1059	-0.0739	0.0320
10	0.0128	0.0000	0.0128	0.0083	-0.0081	0.0002	0.0096	-0.0032	0.0064	0.1059	-0.0619	0.0440
11	0.0064	0.0000	0.0064	0.0083	-0.0086	-0.0003	0.0096	-0.0032	0.0064	0.1059	-0.0502	0.0558
12	0.0064	0.0000	0.0064	0.0166	-0.0088	0.0078	0.0096	-0.0029	0.0067	0.1059	-0.0382	0.0678
13	0.0064	0.0000	0.0064	0.0083	-0.0091	-0.0008	0.0192	-0.0027	0.0165	0.1059	-0.0262	0.0798
14	0.0128	0.0000	0.0128	0.0083	-0.0095	-0.0013	0.0096	-0.0027	0.0069	0.1059	-0.0144	0.0915
exit	0.0064	0.0000	0.0064	0.0083	0.0000	0.0083	0.0096	0.0000	0.0096	0.1059	0.0000	0.1059
TOTAL q _c	0.1213	0.0000	0.1213	0.1408	-0.1028	0.0380	0.1727	-0.0514	0.1213	1.5796	-1.2850	0.2947
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3077	-0.2480	0.0597	0.3766	-0.1522	0.2243	0.4983	-0.1252	0.3731	0.5929	-0.0734	0.5195
2	0.3173	-0.2306	0.0867	0.3765	-0.1436	0.2329	0.4982	-0.1190	0.3792	0.5829	-0.0697	0.5132
3	0.3077	-0.2131	0.0945	0.3765	-0.1353	0.2412	0.4981	-0.1126	0.3855	0.5926	-0.0658	0.5268
4	0.3076	-0.1957	0.1119	0.3861	-0.1269	0.2591	0.4980	-0.1064	0.3915	0.5826	-0.0621	0.5205
5	0.3076	-0.1783	0.1293	0.3764	-0.1183	0.2580	0.4978	-0.1000	0.3978	0.5923	-0.0584	0.5339
6	0.3172	-0.1609	0.1563	0.3763	-0.1100	0.2663	0.4977	-0.0936	0.4041	0.5823	-0.0547	0.5276
7	0.3075	-0.1435	0.1640	0.3763	-0.1017	0.2746	0.4976	-0.0875	0.4101	0.5920	-0.0510	0.5410
8	0.3075	-0.1259	0.1816	0.3762	-0.0931	0.2831	0.4880	-0.0811	0.4069	0.5820	-0.0471	0.5349
9	0.3075	-0.1085	0.1990	0.3762	-0.0847	0.2914	0.4975	-0.0750	0.4225	0.5917	-0.0434	0.5483
10	0.3170	-0.0911	0.2260	0.3761	-0.0764	0.2997	0.4974	-0.0686	0.4288	0.5817	-0.0397	0.5420
11	0.3074	-0.0737	0.2337	0.3761	-0.0678	0.3082	0.4973	-0.0622	0.4351	0.5915	-0.0360	0.5555
12	0.3074	-0.0563	0.2511	0.3856	-0.0595	0.3262	0.4972	-0.0561	0.4411	0.5815	-0.0323	0.5492
13	0.3073	-0.0389	0.2684	0.3760	-0.0512	0.3248	0.4971	-0.0497	0.4474	0.5912	-0.0284	0.5628
14	0.3169	-0.0215	0.2954	0.3759	-0.0426	0.3333	0.4970	-0.0436	0.4534	0.5813	-0.0247	0.5565
exit	0.3073	0.0000	0.3073	0.3759	0.0000	0.3759	0.4969	0.0000	0.4969	0.5910	0.0000	0.5910
TOTAL q _c	4.6508	-1.8860	2.7649	5.6625	-1.3633	4.2991	7.4541	-1.1807	6.2734	8.8095	-0.6867	8.1228
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.6161	-0.0337	0.5824	0.6098	-0.0096	0.6002	0.6197	-0.0017	0.6180	0.6283	-0.0002	0.6280
2	0.6060	-0.0332	0.5728	0.6195	-0.0096	0.6099	0.6294	-0.0017	0.6277	0.6183	-0.0002	0.6180
3	0.6158	-0.0327	0.5831	0.6095	-0.0093	0.6001	0.6194	-0.0017	0.6177	0.6279	-0.0002	0.6277
4	0.6057	-0.0322	0.5735	0.6093	-0.0093	0.6000	0.6192	-0.0017	0.6175	0.6277	-0.0002	0.6275
5	0.6154	-0.0317	0.5838	0.6190	-0.0093	0.6096	0.6289	-0.0015	0.6274	0.6178	-0.0002	0.6175
6	0.6153	-0.0312	0.5841	0.6090	-0.0091	0.5999	0.6189	-0.0015	0.6174	0.6274	-0.0002	0.6271
7	0.6052	-0.0307	0.5745	0.6088	-0.0091	0.5997	0.6187	-0.0015	0.6172	0.6272	-0.0002	0.6270
8	0.6149	-0.0299	0.5850	0.6184	-0.0091	0.6094	0.6283	-0.0015	0.6269	0.6172	-0.0002	0.6170
9	0.6048	-0.0294	0.5754	0.6085	-0.0088	0.5996	0.6184	-0.0015	0.6169	0.6269	-0.0002	0.6266
10	0.6146	-0.0289	0.5857	0.6083	-0.0088	0.5995	0.6182	-0.0012	0.6170	0.6267	-0.0002	0.6264
11	0.6145	-0.0284	0.5860	0.6179	-0.0086	0.6094	0.6278	-0.0012	0.6266	0.6167	-0.0002	0.6165
12	0.6044	-0.0279	0.5765	0.6080	-0.0086	0.5994	0.6179	-0.0012	0.6166	0.6264	-0.0002	0.6261
13	0.6142	-0.0274	0.5868	0.6079	-0.0086	0.5993	0.6177	-0.0012	0.6165	0.6262	-0.0002	0.6260
14	0.6042	-0.0269	0.5772	0.6175	-0.0083	0.6092	0.6274	-0.0012	0.6262	0.6163	-0.0002	0.6161
exit	0.6139	0.0000	0.6139	0.6076	0.0000	0.6076	0.6175	0.0000	0.6175	0.6259	0.0000	0.6259
TOTAL q _c	9.1649	-0.4242	8.7407	9.1789	-0.1261	9.0528	9.3273	-0.0204	9.3070	9.3568	-0.0034	9.3534

Table M2: Coil Set Energy Balance for R3-36 at 12LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0082	-0.0069	0.0013	0.0822	-0.1542	-0.0720
2	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0064	0.0100	0.0904	-0.1434	-0.0530
3	0.0134	0.0000	0.0134	0.0162	-0.0024	0.0138	0.0082	-0.0059	0.0023	0.0822	-0.1324	-0.0502
4	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0054	0.0110	0.0822	-0.1214	-0.0392
5	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0082	-0.0049	0.0033	0.0904	-0.1106	-0.0202
6	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0082	-0.0044	0.0038	0.0822	-0.0996	-0.0174
7	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0039	0.0125	0.0822	-0.0886	-0.0064
8	0.0134	0.0000	0.0134	0.0162	-0.0024	0.0138	0.0082	-0.0034	0.0048	0.0904	-0.0778	0.0126
9	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0029	0.0135	0.0822	-0.0668	0.0154
10	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0082	-0.0024	0.0058	0.0822	-0.0558	0.0264
11	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0082	-0.0020	0.0062	0.0904	-0.0450	0.0454
12	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0015	0.0149	0.0822	-0.0340	0.0482
13	0.0134	0.0000	0.0134	0.0162	-0.0024	0.0138	0.0082	-0.0010	0.0072	0.0822	-0.0230	0.0592
14	0.0067	0.0000	0.0067	0.0081	-0.0024	0.0057	0.0164	-0.0005	0.0159	0.0904	-0.0122	0.0782
exit	0.0067	0.0000	0.0067	0.0081	0.0000	0.0081	0.0082	0.0000	0.0082	0.0822	0.0000	0.0822
TOTAL q _c	0.1208	0.0000	0.1208	0.1459	-0.0343	0.1117	0.1721	-0.0514	0.1208	1.2741	-1.1650	0.1091
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1653	-0.1058	0.0596	0.2652	-0.2213	0.0439	0.4089	-0.1430	0.2659	0.4855	-0.0609	0.4246
2	0.1571	-0.0982	0.0589	0.2651	-0.2058	0.0593	0.4172	-0.1347	0.2825	0.4770	-0.0567	0.4203
3	0.1653	-0.0904	0.0750	0.2734	-0.1906	0.0828	0.4087	-0.1260	0.2827	0.4852	-0.0527	0.4325
4	0.1653	-0.0828	0.0826	0.2651	-0.1754	0.0897	0.4170	-0.1177	0.2993	0.4851	-0.0486	0.4365
5	0.1653	-0.0752	0.0901	0.2650	-0.1599	0.1051	0.4086	-0.1091	0.2995	0.4766	-0.0446	0.4320
6	0.1570	-0.0673	0.0897	0.2650	-0.1447	0.1203	0.4168	-0.1007	0.3161	0.4849	-0.0407	0.4442
7	0.1653	-0.0597	0.1056	0.2650	-0.1295	0.1354	0.4084	-0.0921	0.3163	0.4848	-0.0365	0.4482
8	0.1653	-0.0521	0.1131	0.2732	-0.1141	0.1591	0.4167	-0.0838	0.3329	0.4763	-0.0326	0.4437
9	0.1653	-0.0443	0.1210	0.2649	-0.0989	0.1660	0.4083	-0.0752	0.3331	0.4846	-0.0284	0.4562
10	0.1570	-0.0367	0.1203	0.2649	-0.0837	0.1812	0.4165	-0.0669	0.3497	0.4845	-0.0245	0.4600
11	0.1652	-0.0291	0.1361	0.2649	-0.0683	0.1966	0.4081	-0.0583	0.3499	0.4760	-0.0206	0.4555
12	0.1652	-0.0213	0.1439	0.2648	-0.0531	0.2117	0.4164	-0.0499	0.3665	0.4843	-0.0164	0.4679
13	0.1652	-0.0137	0.1515	0.2731	-0.0379	0.2352	0.4080	-0.0414	0.3666	0.4842	-0.0125	0.4717
14	0.1569	-0.0061	0.1508	0.2648	-0.0225	0.2423	0.4163	-0.0330	0.3832	0.4758	-0.0083	0.4674
exit	0.1652	0.0000	0.1652	0.2648	0.0000	0.2648	0.4079	0.0000	0.4079	0.4840	0.0000	0.4840
TOTAL q _c	2.4460	-0.7827	1.6633	3.9993	-1.7059	2.2934	6.1837	-1.2319	4.9519	7.2287	-0.4840	6.7447
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.5361	-0.0364	0.4997	0.5460	-0.0130	0.5330	0.5489	-0.0022	0.5467	0.5573	-0.0002	0.5571
2	0.5275	-0.0349	0.4927	0.5459	-0.0128	0.5331	0.5572	-0.0022	0.5549	0.5572	-0.0002	0.5569
3	0.5358	-0.0334	0.5024	0.5373	-0.0128	0.5246	0.5486	-0.0022	0.5463	0.5570	-0.0002	0.5568
4	0.5356	-0.0319	0.5037	0.5456	-0.0125	0.5331	0.5568	-0.0022	0.5546	0.5653	-0.0002	0.5651
5	0.5271	-0.0304	0.4967	0.5454	-0.0125	0.5329	0.5482	-0.0022	0.5460	0.5567	-0.0002	0.5565
6	0.5353	-0.0289	0.5064	0.5453	-0.0123	0.5330	0.5565	-0.0020	0.5546	0.5565	-0.0002	0.5563
7	0.5352	-0.0275	0.5077	0.5451	-0.0123	0.5328	0.5479	-0.0020	0.5460	0.5564	-0.0002	0.5561
8	0.5266	-0.0260	0.5007	0.5366	-0.0120	0.5246	0.5562	-0.0020	0.5542	0.5562	-0.0002	0.5560
9	0.5349	-0.0245	0.5104	0.5448	-0.0118	0.5330	0.5476	-0.0020	0.5457	0.5561	-0.0002	0.5558
10	0.5348	-0.0230	0.5117	0.5447	-0.0118	0.5329	0.5559	-0.0020	0.5539	0.5559	-0.0002	0.5557
11	0.5263	-0.0216	0.5047	0.5445	-0.0115	0.5330	0.5473	-0.0020	0.5454	0.5558	-0.0002	0.5555
12	0.5345	-0.0201	0.5145	0.5444	-0.0115	0.5329	0.5556	-0.0020	0.5537	0.5641	-0.0002	0.5638
13	0.5344	-0.0186	0.5158	0.5359	-0.0113	0.5247	0.5471	-0.0017	0.5454	0.5555	-0.0002	0.5553
14	0.5260	-0.0171	0.5088	0.5442	-0.0113	0.5329	0.5554	-0.0017	0.5537	0.5554	0.0000	0.5554
exit	0.5342	0.0000	0.5342	0.5441	0.0000	0.5441	0.5468	0.0000	0.5468	0.5553	0.0000	0.5553
TOTAL q _c	7.9842	-0.3743	7.6099	8.1498	-0.1693	7.9806	8.2761	-0.0282	8.2479	8.3607	-0.0032	8.3575

Table M3: Coil Set Energy Balance for R3-36 at 10LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0205	0.0000	0.0205	0.0206	-0.0159	0.0047	0.0275	-0.0184	0.0091	0.0618	-0.0950	-0.0332
2	0.0205	0.0000	0.0205	0.0274	-0.0149	0.0125	0.0275	-0.0169	0.0106	0.0686	-0.0884	-0.0197
3	0.0205	0.0000	0.0205	0.0206	-0.0137	0.0069	0.0275	-0.0157	0.0118	0.0618	-0.0817	-0.0200
4	0.0205	0.0000	0.0205	0.0274	-0.0125	0.0149	0.0275	-0.0144	0.0130	0.0618	-0.0751	-0.0134
5	0.0205	0.0000	0.0205	0.0206	-0.0115	0.0091	0.0275	-0.0130	0.0145	0.0686	-0.0685	0.0001
6	0.0205	0.0000	0.0205	0.0206	-0.0103	0.0103	0.0275	-0.0117	0.0157	0.0618	-0.0619	-0.0001
7	0.0205	0.0000	0.0205	0.0274	-0.0091	0.0184	0.0275	-0.0105	0.0170	0.0618	-0.0553	0.0065
8	0.0137	0.0000	0.0137	0.0206	-0.0081	0.0125	0.0206	-0.0091	0.0116	0.0686	-0.0487	0.0199
9	0.0205	0.0000	0.0205	0.0274	-0.0069	0.0206	0.0275	-0.0078	0.0196	0.0618	-0.0421	0.0197
10	0.0205	0.0000	0.0205	0.0206	-0.0056	0.0149	0.0275	-0.0066	0.0209	0.0618	-0.0355	0.0263
11	0.0205	0.0000	0.0205	0.0206	-0.0046	0.0159	0.0275	-0.0051	0.0223	0.0686	-0.0289	0.0398
12	0.0205	0.0000	0.0205	0.0274	-0.0034	0.0240	0.0275	-0.0039	0.0236	0.0618	-0.0223	0.0395
13	0.0205	0.0000	0.0205	0.0206	-0.0022	0.0184	0.0275	-0.0027	0.0248	0.0618	-0.0157	0.0461
14	0.0205	0.0000	0.0205	0.0274	-0.0012	0.0262	0.0275	-0.0012	0.0263	0.0686	-0.0091	0.0596
exit	0.0205	0.0000	0.0205	0.0206	0.0000	0.0206	0.0275	0.0000	0.0275	0.0618	0.0000	0.0618
TOTAL q _c	0.3010	0.0000	0.3010	0.3496	-0.1199	0.2297	0.4053	-0.1370	0.2683	0.9609	-0.7281	0.2328
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1737	-0.1810	-0.0073	0.2430	-0.1816	0.0614	0.3398	-0.1104	0.2295	0.4107	-0.0717	0.3390
2	0.1667	-0.1683	-0.0016	0.2360	-0.1693	0.0667	0.3398	-0.1032	0.2365	0.4106	-0.0665	0.3441
3	0.1736	-0.1558	0.0179	0.2429	-0.1573	0.0857	0.3328	-0.0964	0.2364	0.4105	-0.0616	0.3489
4	0.1736	-0.1433	0.0304	0.2360	-0.1453	0.0907	0.3396	-0.0892	0.2504	0.4104	-0.0564	0.3540
5	0.1736	-0.1305	0.0431	0.2429	-0.1330	0.1099	0.3396	-0.0824	0.2572	0.4103	-0.0515	0.3588
6	0.1666	-0.1180	0.0486	0.2429	-0.1210	0.1219	0.3395	-0.0755	0.2640	0.4102	-0.0466	0.3636
7	0.1736	-0.1055	0.0681	0.2359	-0.1090	0.1269	0.3394	-0.0684	0.2711	0.4101	-0.0414	0.3687
8	0.1736	-0.0928	0.0808	0.2428	-0.0967	0.1461	0.3325	-0.0615	0.2710	0.4100	-0.0365	0.3735
9	0.1735	-0.0803	0.0933	0.2358	-0.0847	0.1511	0.3393	-0.0544	0.2850	0.4099	-0.0314	0.3786
10	0.1666	-0.0678	0.0988	0.2427	-0.0727	0.1700	0.3393	-0.0475	0.2918	0.4098	-0.0265	0.3834
11	0.1735	-0.0551	0.1185	0.2427	-0.0605	0.1823	0.3392	-0.0406	0.2986	0.4097	-0.0215	0.3882
12	0.1735	-0.0426	0.1309	0.2358	-0.0485	0.1873	0.3392	-0.0335	0.3056	0.4097	-0.0164	0.3933
13	0.1735	-0.0301	0.1434	0.2427	-0.0365	0.2062	0.3322	-0.0267	0.3055	0.4096	-0.0115	0.3981
14	0.1665	-0.0174	0.1492	0.2357	-0.0242	0.2115	0.3391	-0.0196	0.3195	0.4095	-0.0064	0.4031
exit	0.1735	0.0000	0.1735	0.2426	0.0000	0.2426	0.3390	0.0000	0.3390	0.4094	0.0000	0.4094
TOTAL q _c	2.5756	-1.3883	1.1873	3.6005	-1.4402	2.1603	5.0702	-0.9092	4.1610	6.1502	-0.5458	5.6044
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.4755	-0.0363	0.4392	0.4878	-0.0145	0.4733	0.4964	-0.0032	0.4932	0.5049	-0.0005	0.5045
2	0.4684	-0.0344	0.4340	0.4877	-0.0142	0.4734	0.4963	-0.0029	0.4933	0.5048	-0.0005	0.5043
3	0.4753	-0.0322	0.4431	0.4806	-0.0140	0.4666	0.5031	-0.0029	0.5001	0.5046	-0.0005	0.5041
4	0.4681	-0.0302	0.4379	0.4874	-0.0137	0.4736	0.4959	-0.0029	0.4930	0.5045	-0.0005	0.5040
5	0.4750	-0.0280	0.4470	0.4872	-0.0135	0.4737	0.4958	-0.0027	0.4931	0.5043	-0.0005	0.5038
6	0.4748	-0.0257	0.4491	0.4871	-0.0132	0.4738	0.4956	-0.0027	0.4929	0.5042	-0.0002	0.5039
7	0.4677	-0.0238	0.4439	0.4869	-0.0130	0.4739	0.4955	-0.0027	0.4928	0.5040	-0.0002	0.5038
8	0.4746	-0.0216	0.4530	0.4798	-0.0128	0.4671	0.5023	-0.0027	0.4996	0.4968	-0.0002	0.4966
9	0.4675	-0.0196	0.4479	0.4866	-0.0125	0.4741	0.4952	-0.0025	0.4927	0.5037	-0.0002	0.5034
10	0.4744	-0.0174	0.4570	0.4865	-0.0123	0.4743	0.4950	-0.0025	0.4926	0.5035	-0.0002	0.5033
11	0.4742	-0.0152	0.4591	0.4864	-0.0118	0.4746	0.4949	-0.0025	0.4925	0.5034	-0.0002	0.5032
12	0.4672	-0.0132	0.4539	0.4863	-0.0115	0.4748	0.4948	-0.0022	0.4926	0.5033	-0.0002	0.5030
13	0.4740	-0.0110	0.4630	0.4792	-0.0113	0.4680	0.5016	-0.0022	0.4994	0.5032	-0.0002	0.5029
14	0.4669	-0.0091	0.4579	0.4861	-0.0110	0.4750	0.4946	-0.0022	0.4923	0.5030	-0.0002	0.5028
exit	0.4738	0.0000	0.4738	0.4859	0.0000	0.4859	0.4944	0.0000	0.4944	0.5029	0.0000	0.5029
TOTAL q _c	7.0774	-0.3176	6.7598	7.2815	-0.1793	7.1022	7.4515	-0.0368	7.4147	7.5512	-0.0047	7.5465

Table M4: Coil Set Energy Balance for R3-36 at 9LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0430	0.0000	0.0430	0.0617	-0.1006	-0.0389	0.0681	-0.0570	0.0111	0.1247	-0.1511	-0.0264
2	0.0430	0.0000	0.0430	0.0555	-0.0933	-0.0377	0.0743	-0.0531	0.0212	0.1247	-0.1403	-0.0156
3	0.0368	0.0000	0.0368	0.0617	-0.0862	-0.0245	0.0681	-0.0490	0.0191	0.1247	-0.1298	-0.0051
4	0.0430	0.0000	0.0430	0.0617	-0.0791	-0.0174	0.0743	-0.0448	0.0295	0.1247	-0.1192	0.0054
5	0.0430	0.0000	0.0430	0.0617	-0.0717	-0.0100	0.0681	-0.0409	0.0272	0.1247	-0.1085	0.0162
6	0.0430	0.0000	0.0430	0.0555	-0.0646	-0.0091	0.0681	-0.0367	0.0314	0.1247	-0.0979	0.0267
7	0.0430	0.0000	0.0430	0.0617	-0.0575	0.0042	0.0743	-0.0326	0.0417	0.1247	-0.0874	0.0373
8	0.0368	0.0000	0.0368	0.0617	-0.0502	0.0115	0.0681	-0.0286	0.0395	0.1309	-0.0766	0.0543
9	0.0430	0.0000	0.0430	0.0617	-0.0431	0.0186	0.0743	-0.0245	0.0498	0.1246	-0.0661	0.0586
10	0.0430	0.0000	0.0430	0.0555	-0.0360	0.0195	0.0681	-0.0203	0.0478	0.1246	-0.0556	0.0691
11	0.0430	0.0000	0.0430	0.0617	-0.0286	0.0330	0.0681	-0.0164	0.0517	0.1246	-0.0448	0.0798
12	0.0430	0.0000	0.0430	0.0617	-0.0215	0.0401	0.0743	-0.0122	0.0620	0.1246	-0.0343	0.0904
13	0.0368	0.0000	0.0368	0.0617	-0.0144	0.0472	0.0681	-0.0081	0.0600	0.1246	-0.0237	0.1009
14	0.0430	0.0000	0.0430	0.0555	-0.0071	0.0484	0.0743	-0.0042	0.0701	0.1246	-0.0130	0.1116
exit	0.0430	0.0000	0.0430	0.0617	0.0000	0.0617	0.0681	0.0000	0.0681	0.1246	0.0000	0.1246
TOTAL q _c	0.6263	0.0000	0.6263	0.9006	-0.7538	0.1468	1.0584	-0.4283	0.6301	1.8760	-1.1482	0.7277
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1888	-0.1154	0.0734	0.2398	-0.1517	0.0881	0.3158	-0.0910	0.2248	0.3833	-0.0601	0.3232
2	0.1888	-0.1073	0.0815	0.2398	-0.1419	0.0979	0.3220	-0.0851	0.2369	0.3770	-0.0552	0.3217
3	0.1888	-0.0992	0.0896	0.2397	-0.1318	0.1079	0.3156	-0.0790	0.2367	0.3831	-0.0500	0.3331
4	0.1825	-0.0914	0.0911	0.2397	-0.1218	0.1179	0.3156	-0.0728	0.2428	0.3830	-0.0449	0.3382
5	0.1887	-0.0833	0.1055	0.2397	-0.1120	0.1277	0.3218	-0.0669	0.2549	0.3767	-0.0400	0.3367
6	0.1887	-0.0752	0.1135	0.2397	-0.1019	0.1377	0.3155	-0.0608	0.2547	0.3828	-0.0348	0.3480
7	0.1887	-0.0673	0.1214	0.2396	-0.0918	0.1478	0.3154	-0.0546	0.2608	0.3828	-0.0297	0.3531
8	0.1887	-0.0593	0.1294	0.2396	-0.0820	0.1575	0.3217	-0.0488	0.2729	0.3764	-0.0247	0.3517
9	0.1887	-0.0512	0.1375	0.2396	-0.0720	0.1676	0.3153	-0.0426	0.2727	0.3826	-0.0196	0.3630
10	0.1887	-0.0433	0.1453	0.2395	-0.0619	0.1776	0.3152	-0.0365	0.2788	0.3825	-0.0145	0.3681
11	0.1886	-0.0352	0.1534	0.2395	-0.0521	0.1874	0.3215	-0.0306	0.2909	0.3762	-0.0095	0.3666
12	0.1823	-0.0272	0.1552	0.2395	-0.0421	0.1974	0.3151	-0.0245	0.2907	0.3824	-0.0044	0.3780
13	0.1886	-0.0193	0.1693	0.2394	-0.0321	0.2074	0.3151	-0.0184	0.2967	0.3823	0.0007	0.3830
14	0.1886	-0.0113	0.1773	0.2394	-0.0223	0.2171	0.3213	-0.0125	0.3089	0.3759	0.0056	0.3816
exit	0.1886	0.0000	0.1886	0.2394	0.0000	0.2394	0.3150	0.0000	0.3150	0.3821	0.0000	0.3821
TOTAL q _c	2.8178	-0.8858	1.9320	3.5939	-1.2175	2.3764	4.7620	-0.7240	4.0380	5.7091	-0.3811	5.3280
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.4411	-0.0346	0.4065	0.4580	-0.0133	0.4447	0.4703	-0.0032	0.4671	0.4751	-0.0005	0.4746
2	0.4347	-0.0324	0.4023	0.4578	-0.0130	0.4448	0.4638	-0.0029	0.4609	0.4687	-0.0005	0.4682
3	0.4409	-0.0302	0.4107	0.4641	-0.0125	0.4515	0.4700	-0.0029	0.4671	0.4748	-0.0005	0.4743
4	0.4407	-0.0280	0.4128	0.4575	-0.0123	0.4453	0.4699	-0.0029	0.4669	0.4747	-0.0005	0.4742
5	0.4406	-0.0258	0.4148	0.4574	-0.0120	0.4454	0.4634	-0.0027	0.4607	0.4745	-0.0002	0.4743
6	0.4342	-0.0235	0.4106	0.4573	-0.0118	0.4455	0.4696	-0.0027	0.4669	0.4680	-0.0002	0.4678
7	0.4403	-0.0213	0.4190	0.4571	-0.0113	0.4458	0.4694	-0.0027	0.4667	0.4742	-0.0002	0.4740
8	0.4402	-0.0189	0.4214	0.4633	-0.0110	0.4523	0.4629	-0.0025	0.4605	0.4741	-0.0002	0.4738
9	0.4401	-0.0167	0.4235	0.4569	-0.0108	0.4461	0.4691	-0.0025	0.4667	0.4739	-0.0002	0.4737
10	0.4337	-0.0145	0.4193	0.4567	-0.0105	0.4462	0.4690	-0.0025	0.4665	0.4675	-0.0002	0.4672
11	0.4399	-0.0122	0.4277	0.4566	-0.0100	0.4466	0.4625	-0.0025	0.4601	0.4737	-0.0002	0.4734
12	0.4398	-0.0100	0.4298	0.4565	-0.0098	0.4467	0.4688	-0.0022	0.4665	0.4735	-0.0002	0.4733
13	0.4397	-0.0078	0.4319	0.4627	-0.0095	0.4532	0.4686	-0.0022	0.4664	0.4734	-0.0002	0.4732
14	0.4333	-0.0056	0.4277	0.4563	-0.0093	0.4470	0.4622	-0.0022	0.4600	0.4670	-0.0002	0.4667
exit	0.4395	0.0000	0.4395	0.4562	0.0000	0.4562	0.4684	0.0000	0.4684	0.4732	0.0000	0.4732
TOTAL q _c	6.5790	-0.2816	6.2974	6.8744	-0.1572	6.7172	7.0078	-0.0366	6.9713	7.0862	-0.0044	7.0818

Table M5: Coil Set Energy Balance for R3-36 at 7LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0329	0.0000	0.0329	0.0421	-0.0688	-0.0266	0.0517	-0.0847	-0.0330	0.0898	-0.1330	-0.0432
2	0.0329	0.0000	0.0329	0.0421	-0.0639	-0.0218	0.0564	-0.0788	-0.0224	0.0898	-0.1236	-0.0339
3	0.0329	0.0000	0.0329	0.0421	-0.0592	-0.0171	0.0517	-0.0729	-0.0212	0.0898	-0.1146	-0.0248
4	0.0329	0.0000	0.0329	0.0421	-0.0546	-0.0125	0.0564	-0.0671	-0.0106	0.0850	-0.1055	-0.0205
5	0.0329	0.0000	0.0329	0.0421	-0.0497	-0.0076	0.0517	-0.0612	-0.0095	0.0897	-0.0962	-0.0065
6	0.0329	0.0000	0.0329	0.0421	-0.0450	-0.0029	0.0517	-0.0553	-0.0036	0.0897	-0.0871	0.0026
7	0.0329	0.0000	0.0329	0.0421	-0.0404	0.0017	0.0564	-0.0494	0.0070	0.0897	-0.0781	0.0117
8	0.0376	0.0000	0.0376	0.0421	-0.0355	0.0066	0.0517	-0.0436	0.0082	0.0897	-0.0688	0.0210
9	0.0329	0.0000	0.0329	0.0421	-0.0308	0.0113	0.0564	-0.0377	0.0187	0.0897	-0.0597	0.0300
10	0.0329	0.0000	0.0329	0.0421	-0.0262	0.0159	0.0517	-0.0318	0.0199	0.0897	-0.0507	0.0391
11	0.0329	0.0000	0.0329	0.0421	-0.0213	0.0208	0.0517	-0.0259	0.0258	0.0897	-0.0414	0.0484
12	0.0329	0.0000	0.0329	0.0421	-0.0166	0.0255	0.0564	-0.0201	0.0363	0.0850	-0.0323	0.0527
13	0.0329	0.0000	0.0329	0.0421	-0.0120	0.0301	0.0517	-0.0142	0.0375	0.0897	-0.0232	0.0665
14	0.0329	0.0000	0.0329	0.0421	-0.0071	0.0350	0.0564	-0.0083	0.0481	0.0897	-0.0139	0.0758
exit	0.0329	0.0000	0.0329	0.0421	0.0000	0.0421	0.0517	0.0000	0.0517	0.0897	0.0000	0.0897
TOTAL q _c	0.4982	0.0000	0.4982	0.6318	-0.5310	0.1007	0.8038	-0.6510	0.1529	1.3365	-1.0281	0.3083
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1286	-0.0901	0.0384	0.1476	-0.0836	0.0641	0.2185	-0.0861	0.1325	0.2733	-0.0650	0.2083
2	0.1238	-0.0838	0.0400	0.1524	-0.0777	0.0747	0.2136	-0.0797	0.1340	0.2732	-0.0594	0.2138
3	0.1285	-0.0776	0.0509	0.1476	-0.0718	0.0758	0.2184	-0.0730	0.1454	0.2780	-0.0535	0.2245
4	0.1238	-0.0713	0.0525	0.1476	-0.0659	0.0817	0.2136	-0.0667	0.1469	0.2731	-0.0478	0.2253
5	0.1285	-0.0651	0.0634	0.1523	-0.0600	0.0923	0.2184	-0.0600	0.1583	0.2730	-0.0422	0.2309
6	0.1237	-0.0588	0.0650	0.1476	-0.0541	0.0934	0.2183	-0.0536	0.1647	0.2730	-0.0365	0.2364
7	0.1285	-0.0524	0.0761	0.1475	-0.0482	0.0993	0.2135	-0.0470	0.1664	0.2729	-0.0309	0.2420
8	0.1237	-0.0463	0.0774	0.1523	-0.0424	0.1099	0.2183	-0.0407	0.1776	0.2777	-0.0250	0.2527
9	0.1285	-0.0399	0.0886	0.1475	-0.0365	0.1110	0.2134	-0.0340	0.1794	0.2728	-0.0193	0.2535
10	0.1237	-0.0338	0.0899	0.1475	-0.0306	0.1169	0.2182	-0.0277	0.1905	0.2727	-0.0137	0.2590
11	0.1284	-0.0274	0.1010	0.1522	-0.0247	0.1275	0.2182	-0.0211	0.1971	0.2727	-0.0081	0.2646
12	0.1237	-0.0213	0.1024	0.1475	-0.0188	0.1286	0.2133	-0.0147	0.1986	0.2726	-0.0024	0.2702
13	0.1284	-0.0149	0.1135	0.1474	-0.0130	0.1345	0.2181	-0.0081	0.2100	0.2775	0.0034	0.2809
14	0.1237	-0.0088	0.1148	0.1522	-0.0071	0.1451	0.2132	-0.0017	0.2115	0.2725	0.0091	0.2816
exit	0.1284	0.0000	0.1284	0.1474	0.0000	0.1474	0.2181	0.0000	0.2181	0.2725	0.0000	0.2725
TOTAL q _c	1.8938	-0.6915	1.2023	2.2366	-0.6343	1.6023	3.2451	-0.6140	2.6311	4.1075	-0.3912	3.7162
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3477	-0.0410	0.3067	0.3899	-0.0179	0.3719	0.4008	-0.0049	0.3959	0.4113	-0.0007	0.4105
2	0.3427	-0.0375	0.3051	0.3848	-0.0169	0.3679	0.4007	-0.0047	0.3960	0.4062	-0.0007	0.4055
3	0.3475	-0.0339	0.3136	0.3896	-0.0160	0.3737	0.4054	-0.0047	0.4008	0.4110	-0.0007	0.4102
4	0.3474	-0.0304	0.3170	0.3895	-0.0150	0.3745	0.4004	-0.0044	0.3960	0.4108	-0.0005	0.4103
5	0.3473	-0.0267	0.3205	0.3893	-0.0140	0.3754	0.4003	-0.0042	0.3961	0.4107	-0.0005	0.4102
6	0.3423	-0.0233	0.3190	0.3843	-0.0128	0.3715	0.4001	-0.0039	0.3962	0.4056	-0.0005	0.4051
7	0.3471	-0.0196	0.3275	0.3891	-0.0118	0.3773	0.4000	-0.0039	0.3961	0.4104	-0.0005	0.4099
8	0.3470	-0.0162	0.3308	0.3890	-0.0108	0.3782	0.4047	-0.0037	0.4010	0.4102	-0.0005	0.4097
9	0.3469	-0.0125	0.3344	0.3889	-0.0098	0.3791	0.3997	-0.0034	0.3963	0.4101	-0.0005	0.4096
10	0.3419	-0.0091	0.3329	0.3838	-0.0088	0.3750	0.3996	-0.0034	0.3962	0.4051	-0.0005	0.4046
11	0.3467	-0.0054	0.3414	0.3887	-0.0078	0.3808	0.3995	-0.0032	0.3963	0.4099	-0.0002	0.4096
12	0.3467	-0.0020	0.3447	0.3885	-0.0071	0.3814	0.3994	-0.0029	0.3965	0.4097	-0.0002	0.4095
13	0.3466	0.0017	0.3483	0.3884	-0.0059	0.3826	0.4042	-0.0029	0.4012	0.4096	-0.0002	0.4094
14	0.3416	0.0051	0.3468	0.3834	-0.0051	0.3783	0.3992	-0.0027	0.3965	0.4046	-0.0002	0.4044
exit	0.3464	0.0000	0.3464	0.3883	0.0000	0.3883	0.3991	0.0000	0.3991	0.4094	0.0000	0.4094
TOTAL q _c	5.1858	-0.2506	4.9352	5.8155	-0.1597	5.6558	6.0132	-0.0530	5.9602	6.1346	-0.0066	6.1279

Table M6: Coil Set Energy Balance for R3-36 at 5.5LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0174	0.0000	0.0174	0.0209	-0.0458	-0.0249	0.0350	-0.1119	-0.0769	0.0456	-0.0605	-0.0149
2	0.0173	0.0000	0.0173	0.0244	-0.0423	-0.0179	0.0315	-0.1035	-0.0720	0.0491	-0.0563	-0.0072
3	0.0173	0.0000	0.0173	0.0209	-0.0392	-0.0183	0.0350	-0.0955	-0.0605	0.0456	-0.0519	-0.0063
4	0.0173	0.0000	0.0173	0.0244	-0.0360	-0.0116	0.0350	-0.0874	-0.0524	0.0456	-0.0475	-0.0019
5	0.0173	0.0000	0.0173	0.0209	-0.0325	-0.0116	0.0350	-0.0790	-0.0441	0.0456	-0.0433	0.0022
6	0.0173	0.0000	0.0173	0.0209	-0.0294	-0.0085	0.0315	-0.0710	-0.0395	0.0491	-0.0389	0.0102
7	0.0173	0.0000	0.0173	0.0244	-0.0262	-0.0018	0.0350	-0.0629	-0.0279	0.0456	-0.0345	0.0111
8	0.0208	0.0000	0.0208	0.0209	-0.0228	-0.0019	0.0350	-0.0546	-0.0196	0.0456	-0.0303	0.0152
9	0.0173	0.0000	0.0173	0.0244	-0.0196	0.0048	0.0350	-0.0465	-0.0115	0.0456	-0.0259	0.0196
10	0.0173	0.0000	0.0173	0.0209	-0.0164	0.0045	0.0315	-0.0384	-0.0069	0.0491	-0.0215	0.0275
11	0.0173	0.0000	0.0173	0.0209	-0.0130	0.0079	0.0350	-0.0301	0.0049	0.0456	-0.0174	0.0282
12	0.0173	0.0000	0.0173	0.0244	-0.0098	0.0146	0.0350	-0.0220	0.0130	0.0456	-0.0130	0.0326
13	0.0173	0.0000	0.0173	0.0209	-0.0066	0.0143	0.0350	-0.0139	0.0210	0.0456	-0.0086	0.0370
14	0.0173	0.0000	0.0173	0.0244	-0.0032	0.0212	0.0315	-0.0056	0.0258	0.0491	-0.0044	0.0447
exit	0.0173	0.0000	0.0173	0.0209	0.0000	0.0209	0.0350	0.0000	0.0350	0.0456	0.0000	0.0456
TOTAL q _c	0.2637	0.0000	0.2637	0.3344	-0.3426	-0.0082	0.5107	-0.8223	-0.3116	0.6975	-0.4540	0.2435
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0673	-0.0676	-0.0003	0.0934	-0.1036	-0.0102	0.1389	-0.0679	0.0710	0.1794	-0.0588	0.1206
2	0.0708	-0.0627	0.0081	0.0934	-0.0955	-0.0021	0.1351	-0.0625	0.0726	0.1756	-0.0539	0.1217
3	0.0673	-0.0578	0.0095	0.0898	-0.0877	0.0021	0.1388	-0.0573	0.0815	0.1794	-0.0490	0.1304
4	0.0673	-0.0529	0.0144	0.0934	-0.0798	0.0135	0.1351	-0.0519	0.0831	0.1755	-0.0441	0.1314
5	0.0708	-0.0480	0.0228	0.0933	-0.0717	0.0216	0.1388	-0.0468	0.0920	0.1793	-0.0392	0.1401
6	0.0673	-0.0428	0.0244	0.0933	-0.0639	0.0294	0.1350	-0.0414	0.0937	0.1755	-0.0343	0.1412
7	0.0673	-0.0379	0.0293	0.0933	-0.0561	0.0373	0.1388	-0.0362	0.1025	0.1793	-0.0294	0.1499
8	0.0708	-0.0330	0.0378	0.0897	-0.0480	0.0418	0.1350	-0.0309	0.1042	0.1754	-0.0245	0.1509
9	0.0673	-0.0281	0.0391	0.0933	-0.0401	0.0532	0.1387	-0.0257	0.1130	0.1792	-0.0196	0.1596
10	0.0673	-0.0230	0.0443	0.0933	-0.0323	0.0610	0.1350	-0.0203	0.1147	0.1754	-0.0147	0.1607
11	0.0708	-0.0181	0.0527	0.0933	-0.0242	0.0691	0.1387	-0.0152	0.1235	0.1791	-0.0098	0.1694
12	0.0672	-0.0132	0.0540	0.0933	-0.0164	0.0769	0.1349	-0.0098	0.1252	0.1753	-0.0049	0.1704
13	0.0672	-0.0083	0.0589	0.0897	-0.0086	0.0811	0.1387	-0.0046	0.1340	0.1791	0.0000	0.1791
14	0.0708	-0.0034	0.0674	0.0933	-0.0005	0.0928	0.1349	0.0007	0.1356	0.1753	0.0049	0.1802
exit	0.0672	0.0000	0.0672	0.0933	0.0000	0.0933	0.1386	0.0000	0.1386	0.1790	0.0000	0.1790
TOTAL q _c	1.0267	-0.4970	0.5297	1.3891	-0.7285	0.6607	2.0551	-0.4698	1.5853	2.6618	-0.3773	2.2845
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2561	-0.0464	0.2097	0.3232	-0.0241	0.2991	0.3443	-0.0069	0.3374	0.3559	-0.0012	0.3547
2	0.2560	-0.0417	0.2143	0.3192	-0.0218	0.2973	0.3403	-0.0066	0.3337	0.3519	-0.0010	0.3509
3	0.2559	-0.0373	0.2186	0.3230	-0.0199	0.3031	0.3440	-0.0061	0.3379	0.3556	-0.0010	0.3547
4	0.2558	-0.0326	0.2232	0.3190	-0.0177	0.3013	0.3400	-0.0059	0.3341	0.3555	-0.0010	0.3545
5	0.2558	-0.0282	0.2276	0.3227	-0.0154	0.3073	0.3438	-0.0056	0.3381	0.3514	-0.0010	0.3505
6	0.2557	-0.0235	0.2322	0.3187	-0.0132	0.3055	0.3436	-0.0054	0.3382	0.3552	-0.0010	0.3542
7	0.2557	-0.0191	0.2366	0.3225	-0.0113	0.3113	0.3396	-0.0051	0.3345	0.3551	-0.0007	0.3543
8	0.2556	-0.0145	0.2412	0.3186	-0.0091	0.3095	0.3434	-0.0047	0.3387	0.3510	-0.0007	0.3503
9	0.2556	-0.0100	0.2455	0.3224	-0.0069	0.3155	0.3394	-0.0044	0.3350	0.3548	-0.0007	0.3541
10	0.2555	-0.0054	0.2501	0.3184	-0.0047	0.3137	0.3432	-0.0042	0.3390	0.3547	-0.0007	0.3540
11	0.2554	-0.0010	0.2545	0.3222	-0.0027	0.3195	0.3431	-0.0039	0.3392	0.3507	-0.0007	0.3500
12	0.2554	0.0037	0.2591	0.3182	-0.0005	0.3177	0.3391	-0.0034	0.3357	0.3545	-0.0005	0.3540
13	0.2553	0.0081	0.2634	0.3220	0.0017	0.3237	0.3429	-0.0032	0.3397	0.3544	-0.0005	0.3539
14	0.2553	0.0127	0.2680	0.3180	0.0039	0.3220	0.3389	-0.0029	0.3360	0.3504	-0.0005	0.3499
exit	0.2552	0.0000	0.2552	0.3218	0.0000	0.3218	0.3427	0.0000	0.3427	0.3542	0.0000	0.3542
TOTAL q _c	3.8344	-0.2352	3.5993	4.8099	-0.1415	4.6683	5.1283	-0.0684	5.0599	5.3055	-0.0113	5.2942

Table M7: Coil Set Energy Balance for R3-60 at 14LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0331	0.0000	0.0331	0.0451	-0.0309	0.0141	0.0570	-0.0717	-0.0147	0.1143	-0.1834	-0.0691
2	0.0331	0.0000	0.0331	0.0361	-0.0293	0.0067	0.0570	-0.0686	-0.0117	0.1143	-0.1762	-0.0619
3	0.0331	0.0000	0.0331	0.0451	-0.0279	0.0171	0.0570	-0.0658	-0.0089	0.1238	-0.1687	-0.0449
4	0.0331	0.0000	0.0331	0.0451	-0.0263	0.0188	0.0570	-0.0628	-0.0059	0.1143	-0.1615	-0.0472
5	0.0331	0.0000	0.0331	0.0360	-0.0247	0.0114	0.0475	-0.0600	-0.0126	0.1143	-0.1541	-0.0398
6	0.0331	0.0000	0.0331	0.0451	-0.0230	0.0220	0.0570	-0.0572	-0.0003	0.1143	-0.1466	-0.0323
7	0.0331	0.0000	0.0331	0.0360	-0.0214	0.0146	0.0570	-0.0542	0.0028	0.1143	-0.1394	-0.0251
8	0.0331	0.0000	0.0331	0.0451	-0.0200	0.0251	0.0570	-0.0514	0.0055	0.1238	-0.1319	-0.0081
9	0.0331	0.0000	0.0331	0.0451	-0.0184	0.0267	0.0570	-0.0484	0.0086	0.1143	-0.1247	-0.0104
10	0.0331	0.0000	0.0331	0.0360	-0.0167	0.0193	0.0570	-0.0456	0.0114	0.1143	-0.1173	-0.0030
11	0.0331	0.0000	0.0331	0.0451	-0.0151	0.0299	0.0570	-0.0428	0.0142	0.1143	-0.1098	0.0045
12	0.0331	0.0000	0.0331	0.0451	-0.0135	0.0316	0.0569	-0.0398	0.0172	0.1143	-0.1026	0.0117
13	0.0248	0.0000	0.0248	0.0360	-0.0121	0.0240	0.0475	-0.0370	0.0105	0.1238	-0.0952	0.0286
14	0.0331	0.0000	0.0331	0.0451	-0.0105	0.0346	0.0569	-0.0340	0.0230	0.1143	-0.0879	0.0263
15	0.0331	0.0000	0.0331	0.0451	-0.0088	0.0362	0.0569	-0.0312	0.0258	0.1143	-0.0805	0.0338
16	0.0331	0.0000	0.0331	0.0360	-0.0072	0.0288	0.0569	-0.0284	0.0286	0.1142	-0.0730	0.0412
17	0.0331	0.0000	0.0331	0.0451	-0.0056	0.0395	0.0569	-0.0253	0.0316	0.1142	-0.0658	0.0484
18	0.0331	0.0000	0.0331	0.0451	-0.0042	0.0409	0.0569	-0.0226	0.0344	0.1238	-0.0584	0.0654
19	0.0331	0.0000	0.0331	0.0360	-0.0026	0.0335	0.0569	-0.0195	0.0374	0.1142	-0.0512	0.0631
20	0.0331	0.0000	0.0331	0.0451	-0.0009	0.0441	0.0569	-0.0167	0.0402	0.1142	-0.0437	0.0705
21	0.0331	0.0000	0.0331	0.0360	0.0007	0.0367	0.0475	-0.0140	0.0335	0.1142	-0.0363	0.0779
22	0.0331	0.0000	0.0331	0.0451	0.0023	0.0474	0.0569	-0.0109	0.0460	0.1142	-0.0291	0.0852
23	0.0331	0.0000	0.0331	0.0450	0.0037	0.0488	0.0569	-0.0081	0.0488	0.1237	-0.0216	0.1021
24	0.0331	0.0000	0.0331	0.0360	0.0053	0.0414	0.0569	-0.0051	0.0518	0.1142	-0.0144	0.0998
exit	0.0331	0.0000	0.0331	0.0450	0.0000	0.0450	0.0569	0.0000	0.0569	0.1142	0.0000	0.1142
TOTAL q _c	0.8198	0.0000	0.8198	1.0453	-0.3070	0.7383	1.3952	-0.9211	0.4741	2.9041	-2.3734	0.5308
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2287	-0.2188	0.0099	0.2758	-0.1294	0.1465	0.3781	-0.1057	0.2724	0.4652	-0.0607	0.4045
2	0.2191	-0.2097	0.0095	0.2663	-0.1235	0.1428	0.3875	-0.1001	0.2874	0.4752	-0.0579	0.4173
3	0.2287	-0.2008	0.0278	0.2758	-0.1177	0.1581	0.3779	-0.0947	0.2832	0.4650	-0.0551	0.4099
4	0.2286	-0.1919	0.0367	0.2757	-0.1118	0.1639	0.3779	-0.0891	0.2888	0.4649	-0.0523	0.4127
5	0.2191	-0.1831	0.0360	0.2662	-0.1060	0.1602	0.3872	-0.0837	0.3035	0.4749	-0.0495	0.4255
6	0.2286	-0.1742	0.0544	0.2757	-0.1002	0.1755	0.3777	-0.0781	0.2996	0.4647	-0.0466	0.4181
7	0.2191	-0.1653	0.0537	0.2662	-0.0943	0.1718	0.3871	-0.0727	0.3144	0.4646	-0.0441	0.4206
8	0.2286	-0.1565	0.0721	0.2756	-0.0885	0.1871	0.3776	-0.0671	0.3105	0.4746	-0.0413	0.4334
9	0.2285	-0.1474	0.0812	0.2756	-0.0827	0.1929	0.3775	-0.0617	0.3158	0.4645	-0.0385	0.4260
10	0.2190	-0.1385	0.0805	0.2661	-0.0768	0.1892	0.3869	-0.0564	0.3306	0.4644	-0.0357	0.4287
11	0.2285	-0.1297	0.0988	0.2756	-0.0710	0.2045	0.3774	-0.0508	0.3267	0.4744	-0.0329	0.4415
12	0.2285	-0.1208	0.1077	0.2755	-0.0652	0.2103	0.3774	-0.0454	0.3320	0.4642	-0.0301	0.4342
13	0.2189	-0.1120	0.1070	0.2660	-0.0594	0.2066	0.3868	-0.0398	0.3469	0.4641	-0.0273	0.4369
14	0.2284	-0.1031	0.1253	0.2755	-0.0535	0.2219	0.3773	-0.0345	0.3428	0.4641	-0.0245	0.4396
15	0.2284	-0.0943	0.1342	0.2755	-0.0477	0.2277	0.3772	-0.0289	0.3484	0.4741	-0.0217	0.4524
16	0.2189	-0.0854	0.1335	0.2659	-0.0419	0.2240	0.3866	-0.0235	0.3631	0.4639	-0.0189	0.4451
17	0.2284	-0.0763	0.1521	0.2754	-0.0361	0.2393	0.3771	-0.0182	0.3590	0.4638	-0.0161	0.4478
18	0.2284	-0.0675	0.1609	0.2754	-0.0302	0.2451	0.3771	-0.0126	0.3645	0.4738	-0.0133	0.4606
19	0.2188	-0.0586	0.1602	0.2658	-0.0244	0.2414	0.3864	-0.0072	0.3792	0.4637	-0.0107	0.4530
20	0.2283	-0.0498	0.1786	0.2753	-0.0186	0.2567	0.3770	-0.0016	0.3753	0.4636	-0.0079	0.4557
21	0.2188	-0.0409	0.1779	0.2658	-0.0128	0.2530	0.3863	0.0037	0.3901	0.4736	-0.0051	0.4685
22	0.2283	-0.0321	0.1962	0.2753	-0.0070	0.2683	0.3769	0.0093	0.3862	0.4635	-0.0023	0.4612
23	0.2283	-0.0233	0.2050	0.2752	-0.0012	0.2741	0.3768	0.0147	0.3915	0.4634	0.0005	0.4639
24	0.2188	-0.0142	0.2046	0.2657	0.0047	0.2704	0.3862	0.0202	0.4064	0.4734	0.0033	0.4767
exit	0.2283	0.0000	0.2283	0.2752	0.0000	0.2752	0.3767	0.0000	0.3767	0.4633	0.0000	0.4633
TOTAL q _c	5.6260	-2.7941	2.8320	6.8022	-1.4953	5.3069	9.5188	-1.0238	8.4950	11.6851	-0.6882	10.9969
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.4910	-0.0271	0.4639	0.4855	-0.0082	0.4773	0.4931	-0.0016	0.4915	0.5061	-0.0002	0.5058
2	0.4909	-0.0264	0.4645	0.4951	-0.0079	0.4871	0.5027	-0.0014	0.5013	0.4962	-0.0002	0.4960
3	0.5008	-0.0257	0.4751	0.4853	-0.0079	0.4773	0.4929	-0.0014	0.4915	0.5058	-0.0002	0.5056
4	0.4907	-0.0250	0.4657	0.4948	-0.0077	0.4871	0.5024	-0.0014	0.5010	0.5057	-0.0002	0.5055
5	0.4906	-0.0243	0.4663	0.4850	-0.0077	0.4773	0.4927	-0.0014	0.4913	0.5056	-0.0002	0.5054
6	0.4905	-0.0236	0.4669	0.4849	-0.0075	0.4775	0.5022	-0.0014	0.5008	0.4958	-0.0002	0.4955
7	0.5004	-0.0231	0.4773	0.4945	-0.0072	0.4873	0.4924	-0.0012	0.4913	0.5054	-0.0002	0.5052
8	0.4903	-0.0224	0.4679	0.4847	-0.0072	0.4775	0.5020	-0.0012	0.5008	0.5053	-0.0002	0.5050
9	0.4902	-0.0217	0.4685	0.4943	-0.0070	0.4873	0.4922	-0.0012	0.4911	0.4954	-0.0002	0.4952
10	0.4901	-0.0210	0.4691	0.4845	-0.0070	0.4775	0.4921	-0.0012	0.4909	0.5050	-0.0002	0.5048
11	0.4999	-0.0203	0.4797	0.4844	-0.0068	0.4776	0.5016	-0.0012	0.5005	0.5049	-0.0002	0.5047
12	0.4898	-0.0196	0.4703	0.4940	-0.0068	0.4872	0.4919	-0.0009	0.4910	0.5048	-0.0002	0.5046
13	0.4898	-0.0189	0.4709	0.4842	-0.0065	0.4777	0.5014	-0.0009	0.5005	0.4950	-0.0002	0.4948
14	0.4897	-0.0182	0.4715	0.4938	-0.0063	0.4875	0.4917	-0.0009	0.4907	0.5046	-0.0002	0.5044
15	0.4996	-0.0175	0.4821	0.4840	-0.0063	0.4777	0.5012	-0.0009	0.5003	0.5045	-0.0002	0.5043
16	0.4895	-0.0168	0.4727	0.4839	-0.0061	0.4779	0.4915	-0.0007	0.4908	0.5044	-0.0002	0.5042
17	0.4894	-0.0161	0.4734	0.4935	-0.0061	0.4875	0.4914	-0.0007	0.4907	0.4946	-0.0002	0.4944
18	0.4893	-0.0154	0.4740	0.4838	-0.0058	0.4779	0.5010	-0.0007	0.5003	0.5042	-0.0002	0.5040
19	0.4992	-0.0149	0.4844	0.4933	-0.0056	0.4878	0.4912	-0.0007	0.4905	0.5041	-0.0002	0.5039
20	0.4892	-0.0142	0.4750	0.4836	-0.0056	0.4780	0.5008	-0.0007	0.5001	0.4944	-0.0002	0.4941
21	0.4891	-0.0135	0.4756	0.4835	-0.0054	0.4782	0.4911	-0.0005	0.4906	0.5040	-0.0002	0.5037
22	0.4890	-0.0128	0.4762	0.4931	-0.0054	0.4877	0.5006	-0.0005	0.5001	0.5039	-0.0002	0.5036
23	0.4989	-0.0121	0.4868	0.4833	-0.0051	0.4782	0.4909	-0.0005	0.4904	0.5038	-0.0002	0.5036
24	0.4889	-0.0114	0.4775	0.4929	-0.0051	0.4878	0.5004	-0.0005	0.5000	0.4940	-0.0002	0.4938
exit	0.4888	0.0000	0.4888	0.4832	0.0000	0.4832	0.4907	0.0000	0.4907	0.5036	0.0000	0.5036
TOTAL q _c	12.3056	-0.4616	11.8441	12.2032	-0.1581	12.0451	12.4023	-0.0236	12.3787	12.5513	-0.0056	12.5457

Table M8: Coil Set Energy Balance for R3-60 at 12LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0160	0.0000	0.0160	0.0244	-0.0381	-0.0137	0.0568	-0.2657	-0.2089	0.1065	-0.1520	-0.0455
2	0.0160	0.0000	0.0160	0.0163	-0.0365	-0.0202	0.0649	-0.2548	-0.1898	0.1065	-0.1455	-0.0390
3	0.0160	0.0000	0.0160	0.0244	-0.0351	-0.0107	0.0568	-0.2436	-0.1868	0.0983	-0.1392	-0.0409
4	0.0160	0.0000	0.0160	0.0163	-0.0335	-0.0172	0.0568	-0.2327	-0.1758	0.1065	-0.1327	-0.0262
5	0.0160	0.0000	0.0160	0.0244	-0.0321	-0.0077	0.0649	-0.2215	-0.1565	0.1065	-0.1264	-0.0199
6	0.0160	0.0000	0.0160	0.0163	-0.0307	-0.0144	0.0568	-0.2103	-0.1535	0.1065	-0.1201	-0.0136
7	0.0080	0.0000	0.0080	0.0244	-0.0291	-0.0047	0.0568	-0.1994	-0.1426	0.1065	-0.1136	-0.0071
8	0.0160	0.0000	0.0160	0.0163	-0.0277	-0.0114	0.0649	-0.1882	-0.1233	0.0983	-0.1073	-0.0090
9	0.0160	0.0000	0.0160	0.0244	-0.0260	-0.0016	0.0568	-0.1773	-0.1204	0.1064	-0.1008	0.0057
10	0.0160	0.0000	0.0160	0.0244	-0.0247	-0.0002	0.0568	-0.1661	-0.1093	0.1064	-0.0945	0.0120
11	0.0160	0.0000	0.0160	0.0163	-0.0233	-0.0070	0.0649	-0.1549	-0.0900	0.1064	-0.0882	0.0183
12	0.0160	0.0000	0.0160	0.0244	-0.0216	0.0028	0.0568	-0.1440	-0.0872	0.1064	-0.0817	0.0248
13	0.0160	0.0000	0.0160	0.0163	-0.0202	-0.0040	0.0568	-0.1328	-0.0760	0.0982	-0.0754	0.0229
14	0.0160	0.0000	0.0160	0.0244	-0.0186	0.0058	0.0568	-0.1219	-0.0651	0.1064	-0.0689	0.0376
15	0.0160	0.0000	0.0160	0.0163	-0.0172	-0.0009	0.0649	-0.1107	-0.0458	0.1064	-0.0626	0.0438
16	0.0160	0.0000	0.0160	0.0244	-0.0158	0.0086	0.0568	-0.0995	-0.0427	0.1064	-0.0563	0.0501
17	0.0160	0.0000	0.0160	0.0244	-0.0142	0.0102	0.0568	-0.0886	-0.0318	0.1064	-0.0498	0.0566
18	0.0160	0.0000	0.0160	0.0163	-0.0128	0.0035	0.0649	-0.0774	-0.0125	0.0982	-0.0435	0.0547
19	0.0080	0.0000	0.0080	0.0244	-0.0112	0.0132	0.0568	-0.0665	-0.0097	0.1064	-0.0370	0.0694
20	0.0160	0.0000	0.0160	0.0163	-0.0098	0.0065	0.0568	-0.0554	0.0014	0.1064	-0.0307	0.0757
21	0.0160	0.0000	0.0160	0.0244	-0.0084	0.0160	0.0649	-0.0442	0.0207	0.1064	-0.0244	0.0820
22	0.0160	0.0000	0.0160	0.0163	-0.0067	0.0095	0.0568	-0.0333	0.0235	0.1064	-0.0179	0.0885
23	0.0160	0.0000	0.0160	0.0244	-0.0053	0.0191	0.0568	-0.0221	0.0347	0.0982	-0.0116	0.0866
24	0.0160	0.0000	0.0160	0.0163	-0.0037	0.0125	0.0649	-0.0112	0.0537	0.1064	-0.0051	0.1013
exit	0.0160	0.0000	0.0160	0.0244	0.0000	0.0244	0.0568	0.0000	0.0568	0.1064	0.0000	0.1064
TOTAL q _c	0.3844	0.0000	0.3844	0.5206	-0.5023	0.0183	1.4851	-3.3219	-1.8368	2.6197	-1.8848	0.7349
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1897	-0.1838	0.0059	0.2494	-0.1690	0.0804	0.3350	-0.0772	0.2578	0.3948	-0.0569	0.3379
2	0.1896	-0.1759	0.0138	0.2494	-0.1608	0.0886	0.3266	-0.0728	0.2538	0.3948	-0.0534	0.3413
3	0.1896	-0.1679	0.0217	0.2493	-0.1524	0.0969	0.3349	-0.0683	0.2666	0.3947	-0.0502	0.3445
4	0.1896	-0.1600	0.0296	0.2493	-0.1442	0.1051	0.3348	-0.0639	0.2710	0.3862	-0.0466	0.3396
5	0.1896	-0.1521	0.0375	0.2493	-0.1361	0.1132	0.3264	-0.0592	0.2672	0.3945	-0.0434	0.3511
6	0.1896	-0.1441	0.0454	0.2493	-0.1279	0.1214	0.3347	-0.0548	0.2800	0.3944	-0.0401	0.3543
7	0.1896	-0.1360	0.0536	0.2575	-0.1197	0.1378	0.3263	-0.0503	0.2760	0.3944	-0.0366	0.3578
8	0.1896	-0.1281	0.0615	0.2492	-0.1113	0.1379	0.3346	-0.0459	0.2887	0.3943	-0.0333	0.3609
9	0.1895	-0.1201	0.0694	0.2492	-0.1032	0.1460	0.3346	-0.0415	0.2931	0.3942	-0.0298	0.3644
10	0.1895	-0.1122	0.0773	0.2492	-0.0950	0.1542	0.3262	-0.0370	0.2891	0.3857	-0.0266	0.3592
11	0.1895	-0.1043	0.0852	0.2491	-0.0868	0.1623	0.3345	-0.0326	0.3019	0.3941	-0.0233	0.3708
12	0.1895	-0.0964	0.0931	0.2491	-0.0787	0.1704	0.3344	-0.0282	0.3063	0.3940	-0.0198	0.3742
13	0.1977	-0.0884	0.1093	0.2491	-0.0703	0.1788	0.3260	-0.0235	0.3025	0.3939	-0.0165	0.3774
14	0.1895	-0.0803	0.1092	0.2491	-0.0621	0.1869	0.3343	-0.0191	0.3153	0.3939	-0.0130	0.3808
15	0.1895	-0.0724	0.1171	0.2490	-0.0540	0.1950	0.3343	-0.0147	0.3196	0.3938	-0.0098	0.3840
16	0.1894	-0.0645	0.1250	0.2490	-0.0458	0.2032	0.3259	-0.0102	0.3157	0.3854	-0.0065	0.3789
17	0.1894	-0.0565	0.1329	0.2490	-0.0377	0.2113	0.3342	-0.0058	0.3284	0.3937	-0.0030	0.3907
18	0.1894	-0.0486	0.1408	0.2490	-0.0293	0.2196	0.3342	-0.0014	0.3328	0.3936	0.0002	0.3939
19	0.1894	-0.0407	0.1487	0.2572	-0.0212	0.2361	0.3258	0.0030	0.3288	0.3936	0.0037	0.3973
20	0.1894	-0.0328	0.1566	0.2489	-0.0130	0.2359	0.3341	0.0074	0.3415	0.3935	0.0070	0.4005
21	0.1894	-0.0249	0.1645	0.2489	-0.0049	0.2440	0.3257	0.0121	0.3378	0.3934	0.0102	0.4037
22	0.1894	-0.0167	0.1726	0.2489	0.0033	0.2521	0.3340	0.0165	0.3505	0.3850	0.0137	0.3987
23	0.1893	-0.0088	0.1805	0.2488	0.0116	0.2605	0.3340	0.0209	0.3549	0.3933	0.0170	0.4103
24	0.1893	-0.0009	0.1884	0.2488	0.0198	0.2686	0.3256	0.0253	0.3509	0.3933	0.0205	0.4137
exit	0.1893	0.0000	0.1893	0.2488	0.0000	0.2488	0.3339	0.0000	0.3339	0.3932	0.0000	0.3932
TOTAL q _c	4.7453	-2.2165	2.5288	6.2437	-1.7889	4.4548	8.2850	-0.6211	7.6639	9.8158	-0.4366	9.3792
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.4337	-0.0292	0.4045	0.4351	-0.0093	0.4257	0.4457	-0.0019	0.4438	0.4564	-0.0002	0.4562
2	0.4421	-0.0280	0.4140	0.4433	-0.0091	0.4342	0.4456	-0.0019	0.4437	0.4563	-0.0002	0.4561
3	0.4335	-0.0271	0.4064	0.4349	-0.0091	0.4257	0.4539	-0.0019	0.4521	0.4478	-0.0002	0.4475
4	0.4334	-0.0259	0.4075	0.4348	-0.0089	0.4259	0.4454	-0.0019	0.4435	0.4561	-0.0002	0.4559
5	0.4333	-0.0250	0.4083	0.4347	-0.0089	0.4258	0.4453	-0.0016	0.4437	0.4560	-0.0002	0.4558
6	0.4417	-0.0238	0.4179	0.4429	-0.0086	0.4343	0.4452	-0.0016	0.4436	0.4559	-0.0002	0.4557
7	0.4331	-0.0229	0.4102	0.4345	-0.0086	0.4258	0.4535	-0.0016	0.4519	0.4558	-0.0002	0.4555
8	0.4330	-0.0217	0.4113	0.4344	-0.0084	0.4260	0.4450	-0.0016	0.4434	0.4472	-0.0002	0.4470
9	0.4414	-0.0207	0.4206	0.4426	-0.0084	0.4342	0.4449	-0.0016	0.4433	0.4556	-0.0002	0.4553
10	0.4328	-0.0198	0.4130	0.4342	-0.0082	0.4260	0.4448	-0.0014	0.4434	0.4555	-0.0002	0.4552
11	0.4327	-0.0186	0.4141	0.4341	-0.0082	0.4259	0.4531	-0.0014	0.4517	0.4553	-0.0002	0.4551
12	0.4326	-0.0177	0.4149	0.4340	-0.0079	0.4260	0.4446	-0.0014	0.4432	0.4552	-0.0002	0.4550
13	0.4410	-0.0165	0.4245	0.4422	-0.0079	0.4343	0.4445	-0.0014	0.4431	0.4467	-0.0002	0.4465
14	0.4325	-0.0156	0.4169	0.4338	-0.0077	0.4261	0.4444	-0.0014	0.4430	0.4551	-0.0002	0.4548
15	0.4324	-0.0144	0.4180	0.4337	-0.0075	0.4263	0.4527	-0.0014	0.4513	0.4550	-0.0002	0.4547
16	0.4323	-0.0135	0.4188	0.4337	-0.0075	0.4262	0.4442	-0.0012	0.4431	0.4549	-0.0002	0.4547
17	0.4407	-0.0126	0.4281	0.4419	-0.0074	0.4345	0.4442	-0.0012	0.4430	0.4548	0.0000	0.4548
18	0.4322	-0.0114	0.4208	0.4335	-0.0072	0.4263	0.4441	-0.0012	0.4429	0.4463	0.0000	0.4463
19	0.4321	-0.0105	0.4216	0.4334	-0.0072	0.4262	0.4524	-0.0012	0.4512	0.4546	0.0000	0.4546
20	0.4405	-0.0093	0.4312	0.4417	-0.0070	0.4347	0.4439	-0.0012	0.4428	0.4546	0.0000	0.4546
21	0.4319	-0.0084	0.4236	0.4333	-0.0070	0.4263	0.4438	-0.0009	0.4429	0.4545	0.0000	0.4545
22	0.4319	-0.0072	0.4247	0.4332	-0.0067	0.4264	0.4438	-0.0009	0.4428	0.4544	0.0000	0.4544
23	0.4318	-0.0063	0.4255	0.4331	-0.0067	0.4264	0.4521	-0.0009	0.4511	0.4459	0.0000	0.4459
24	0.4402	-0.0051	0.4351	0.4414	-0.0065	0.4349	0.4436	-0.0009	0.4427	0.4542	0.0000	0.4542
exit	0.4317	0.0000	0.4317	0.4330	0.0000	0.4330	0.4436	0.0000	0.4436	0.4542	0.0000	0.4542
TOTAL q _c	10.8742	-0.4112	10.4631	10.9070	-0.1899	10.7171	11.1642	-0.0336	11.1307	11.3382	-0.0037	11.3345

Table M9: Coil Set Energy Balance for R3-60 at 10LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0274	0.0000	0.0274	0.0345	-0.0693	-0.0349	0.0483	-0.1052	-0.0569	0.0830	-0.1285	-0.0455
2	0.0274	0.0000	0.0274	0.0413	-0.0663	-0.0249	0.0483	-0.1007	-0.0524	0.0830	-0.1231	-0.0401
3	0.0274	0.0000	0.0274	0.0345	-0.0635	-0.0290	0.0552	-0.0965	-0.0414	0.0761	-0.1180	-0.0419
4	0.0274	0.0000	0.0274	0.0345	-0.0605	-0.0260	0.0483	-0.0921	-0.0438	0.0830	-0.1126	-0.0296
5	0.0342	0.0000	0.0342	0.0413	-0.0577	-0.0163	0.0483	-0.0879	-0.0396	0.0830	-0.1073	-0.0243
6	0.0274	0.0000	0.0274	0.0345	-0.0549	-0.0204	0.0483	-0.0837	-0.0355	0.0830	-0.1019	-0.0189
7	0.0274	0.0000	0.0274	0.0413	-0.0519	-0.0105	0.0483	-0.0793	-0.0310	0.0761	-0.0966	-0.0205
8	0.0274	0.0000	0.0274	0.0345	-0.0491	-0.0146	0.0552	-0.0751	-0.0199	0.0830	-0.0914	-0.0085
9	0.0274	0.0000	0.0274	0.0345	-0.0461	-0.0116	0.0483	-0.0707	-0.0224	0.0830	-0.0861	-0.0031
10	0.0274	0.0000	0.0274	0.0413	-0.0433	-0.0019	0.0483	-0.0665	-0.0182	0.0830	-0.0807	0.0022
11	0.0274	0.0000	0.0274	0.0345	-0.0405	-0.0060	0.0483	-0.0623	-0.0140	0.0760	-0.0754	0.0007
12	0.0274	0.0000	0.0274	0.0345	-0.0374	-0.0030	0.0483	-0.0579	-0.0096	0.0830	-0.0700	0.0129
13	0.0342	0.0000	0.0342	0.0413	-0.0347	0.0067	0.0552	-0.0537	0.0015	0.0830	-0.0649	0.0181
14	0.0274	0.0000	0.0274	0.0345	-0.0316	0.0028	0.0483	-0.0493	-0.0010	0.0830	-0.0596	0.0234
15	0.0274	0.0000	0.0274	0.0345	-0.0288	0.0056	0.0483	-0.0451	0.0032	0.0760	-0.0542	0.0218
16	0.0274	0.0000	0.0274	0.0413	-0.0260	0.0153	0.0483	-0.0409	0.0073	0.0829	-0.0488	0.0341
17	0.0274	0.0000	0.0274	0.0345	-0.0230	0.0114	0.0483	-0.0365	0.0118	0.0829	-0.0435	0.0394
18	0.0274	0.0000	0.0274	0.0344	-0.0202	0.0142	0.0552	-0.0323	0.0229	0.0829	-0.0384	0.0446
19	0.0274	0.0000	0.0274	0.0413	-0.0172	0.0241	0.0483	-0.0279	0.0204	0.0760	-0.0330	0.0430
20	0.0274	0.0000	0.0274	0.0344	-0.0144	0.0200	0.0483	-0.0237	0.0246	0.0829	-0.0277	0.0553
21	0.0342	0.0000	0.0342	0.0413	-0.0116	0.0297	0.0483	-0.0195	0.0287	0.0829	-0.0223	0.0606
22	0.0274	0.0000	0.0274	0.0344	-0.0086	0.0258	0.0483	-0.0151	0.0332	0.0829	-0.0170	0.0660
23	0.0274	0.0000	0.0274	0.0344	-0.0058	0.0286	0.0552	-0.0109	0.0442	0.0760	-0.0119	0.0642
24	0.0274	0.0000	0.0274	0.0413	-0.0028	0.0385	0.0483	-0.0065	0.0418	0.0829	-0.0065	0.0764
exit	0.0274	0.0000	0.0274	0.0344	0.0000	0.0344	0.0483	0.0000	0.0483	0.0829	0.0000	0.0829
TOTAL q _c	0.7054	0.0000	0.7054	0.9233	-0.8652	0.0581	1.2416	-1.3398	-0.0982	2.0324	-1.6194	0.4131
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1310	-0.1327	-0.0018	0.1726	-0.1731	-0.0005	0.2577	-0.1017	0.1560	0.3117	-0.0553	0.2564
2	0.1309	-0.1271	0.0038	0.1795	-0.1654	0.0140	0.2646	-0.0961	0.1686	0.3047	-0.0518	0.2529
3	0.1240	-0.1218	0.0023	0.1725	-0.1579	0.0146	0.2576	-0.0905	0.1672	0.3116	-0.0485	0.2631
4	0.1309	-0.1162	0.0147	0.1725	-0.1502	0.0223	0.2576	-0.0848	0.1727	0.3115	-0.0450	0.2665
5	0.1309	-0.1108	0.0201	0.1725	-0.1428	0.0297	0.2645	-0.0792	0.1853	0.3115	-0.0415	0.2700
6	0.1309	-0.1055	0.0255	0.1794	-0.1353	0.0441	0.2575	-0.0736	0.1839	0.3045	-0.0380	0.2665
7	0.1309	-0.0999	0.0310	0.1725	-0.1276	0.0449	0.2575	-0.0678	0.1897	0.3113	-0.0345	0.2769
8	0.1240	-0.0945	0.0295	0.1725	-0.1202	0.0523	0.2644	-0.0622	0.2022	0.3113	-0.0312	0.2801
9	0.1309	-0.0889	0.0420	0.1794	-0.1125	0.0669	0.2574	-0.0566	0.2008	0.3043	-0.0277	0.2766
10	0.1309	-0.0836	0.0473	0.1724	-0.1050	0.0674	0.2574	-0.0510	0.2064	0.3112	-0.0242	0.2870
11	0.1309	-0.0780	0.0529	0.1724	-0.0975	0.0749	0.2643	-0.0454	0.2189	0.3111	-0.0207	0.2904
12	0.1309	-0.0726	0.0583	0.1724	-0.0899	0.0826	0.2573	-0.0398	0.2175	0.3111	-0.0172	0.2939
13	0.1240	-0.0670	0.0570	0.1793	-0.0824	0.0969	0.2573	-0.0342	0.2230	0.3041	-0.0140	0.2902
14	0.1308	-0.0617	0.0692	0.1724	-0.0747	0.0977	0.2572	-0.0286	0.2286	0.3110	-0.0105	0.3005
15	0.1308	-0.0561	0.0748	0.1724	-0.0673	0.1051	0.2642	-0.0230	0.2411	0.3110	-0.0070	0.3040
16	0.1308	-0.0507	0.0801	0.1724	-0.0598	0.1125	0.2572	-0.0175	0.2397	0.3109	-0.0035	0.3074
17	0.1308	-0.0451	0.0857	0.1792	-0.0521	0.1271	0.2571	-0.0119	0.2453	0.3039	0.0000	0.3039
18	0.1239	-0.0398	0.0842	0.1723	-0.0447	0.1277	0.2641	-0.0063	0.2578	0.3108	0.0033	0.3141
19	0.1308	-0.0342	0.0966	0.1723	-0.0370	0.1353	0.2571	-0.0005	0.2566	0.3108	0.0067	0.3175
20	0.1308	-0.0288	0.1020	0.1792	-0.0295	0.1496	0.2570	0.0051	0.2622	0.3038	0.0102	0.3140
21	0.1308	-0.0235	0.1073	0.1723	-0.0221	0.1502	0.2640	0.0107	0.2747	0.3107	0.0137	0.3244
22	0.1308	-0.0179	0.1129	0.1723	-0.0144	0.1578	0.2570	0.0163	0.2733	0.3106	0.0172	0.3278
23	0.1239	-0.0126	0.1113	0.1723	-0.0070	0.1653	0.2570	0.0219	0.2788	0.3106	0.0205	0.3311
24	0.1308	-0.0070	0.1238	0.1791	0.0007	0.1798	0.2639	0.0274	0.2913	0.3037	0.0239	0.3276
exit	0.1308	0.0000	0.1308	0.1722	0.0000	0.1722	0.2569	0.0000	0.2569	0.3105	0.0000	0.3105
TOTAL q _c	3.2370	-1.6759	1.5611	4.3582	-2.0677	2.2905	6.4876	-0.8893	5.5983	7.7283	-0.3751	7.3532
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3758	-0.0388	0.3371	0.3880	-0.0126	0.3754	0.3950	-0.0028	0.3922	0.4044	-0.0005	0.4039
2	0.3688	-0.0367	0.3321	0.3879	-0.0124	0.3755	0.4018	-0.0028	0.3990	0.4043	-0.0005	0.4038
3	0.3757	-0.0345	0.3411	0.3878	-0.0119	0.3759	0.3948	-0.0028	0.3920	0.4042	-0.0005	0.4037
4	0.3686	-0.0324	0.3362	0.3877	-0.0117	0.3760	0.4016	-0.0028	0.3988	0.4041	-0.0002	0.4039
5	0.3755	-0.0306	0.3449	0.3876	-0.0114	0.3762	0.3946	-0.0026	0.3921	0.4040	-0.0002	0.4038
6	0.3754	-0.0285	0.3469	0.3875	-0.0112	0.3763	0.3945	-0.0026	0.3920	0.4039	-0.0002	0.4037
7	0.3684	-0.0263	0.3420	0.3874	-0.0107	0.3767	0.4013	-0.0026	0.3988	0.4038	-0.0002	0.4036
8	0.3752	-0.0242	0.3510	0.3873	-0.0105	0.3768	0.3943	-0.0023	0.3920	0.4037	-0.0002	0.4035
9	0.3682	-0.0221	0.3460	0.3872	-0.0103	0.3770	0.4011	-0.0023	0.3988	0.4036	-0.0002	0.4034
10	0.3750	-0.0200	0.3550	0.3871	-0.0100	0.3771	0.3941	-0.0023	0.3918	0.4035	-0.0002	0.4033
11	0.3750	-0.0179	0.3570	0.3870	-0.0098	0.3772	0.3940	-0.0023	0.3917	0.4034	-0.0002	0.4031
12	0.3680	-0.0158	0.3521	0.3870	-0.0093	0.3776	0.4008	-0.0021	0.3987	0.4033	-0.0002	0.4030
13	0.3748	-0.0140	0.3609	0.3938	-0.0091	0.3847	0.3938	-0.0021	0.3917	0.4032	-0.0002	0.4030
14	0.3678	-0.0119	0.3560	0.3868	-0.0089	0.3780	0.4007	-0.0021	0.3986	0.4031	-0.0002	0.4029
15	0.3747	-0.0098	0.3649	0.3867	-0.0086	0.3781	0.3937	-0.0021	0.3916	0.4030	-0.0002	0.4028
16	0.3746	-0.0077	0.3669	0.3867	-0.0081	0.3785	0.3936	-0.0019	0.3918	0.4030	-0.0002	0.4027
17	0.3676	-0.0056	0.3620	0.3866	-0.0079	0.3787	0.4004	-0.0019	0.3986	0.4029	-0.0002	0.4026
18	0.3745	-0.0035	0.3710	0.3865	-0.0077	0.3788	0.3935	-0.0019	0.3916	0.4028	-0.0002	0.4026
19	0.3675	-0.0014	0.3661	0.3864	-0.0074	0.3790	0.4003	-0.0016	0.3987	0.4027	-0.0002	0.4025
20	0.3744	0.0007	0.3751	0.3864	-0.0072	0.3791	0.3933	-0.0016	0.3917	0.4026	0.0000	0.4026
21	0.3743	0.0026	0.3769	0.3863	-0.0067	0.3795	0.3932	-0.0016	0.3916	0.4025	0.0000	0.4025
22	0.3673	0.0047	0.3720	0.3862	-0.0065	0.3797	0.4001	-0.0016	0.3984	0.4025	0.0000	0.4025
23	0.3742	0.0067	0.3809	0.3862	-0.0063	0.3799	0.3931	-0.0014	0.3917	0.4024	0.0000	0.4024
24	0.3672	0.0088	0.3760	0.3861	-0.0060	0.3801	0.3999	-0.0014	0.3985	0.4023	0.0000	0.4023
exit	0.3741	0.0000	0.3741	0.3860	0.0000	0.3860	0.3930	0.0000	0.3930	0.4023	0.0000	0.4023
TOTAL q _c	9.3026	-0.3583	8.9443	9.6802	-0.2224	9.4578	9.9168	-0.0515	9.8653	10.0815	-0.0051	10.0763

Table M10: Coil Set Energy Balance for R3-60 at 9LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0245	0.0000	0.0245	0.0369	-0.1093	-0.0725	0.0493	-0.1117	-0.0624	0.0746	-0.1217	-0.0472
2	0.0245	0.0000	0.0245	0.0368	-0.1047	-0.0678	0.0493	-0.1068	-0.0576	0.0746	-0.1166	-0.0420
3	0.0184	0.0000	0.0184	0.0307	-0.1000	-0.0693	0.0431	-0.1021	-0.0591	0.0808	-0.1113	-0.0305
4	0.0245	0.0000	0.0245	0.0368	-0.0954	-0.0585	0.0492	-0.0973	-0.0480	0.0746	-0.1061	-0.0316
5	0.0245	0.0000	0.0245	0.0368	-0.0907	-0.0539	0.0492	-0.0926	-0.0434	0.0746	-0.1010	-0.0264
6	0.0245	0.0000	0.0245	0.0368	-0.0861	-0.0492	0.0492	-0.0879	-0.0387	0.0746	-0.0959	-0.0213
7	0.0184	0.0000	0.0184	0.0307	-0.0814	-0.0507	0.0492	-0.0831	-0.0338	0.0808	-0.0908	-0.0100
8	0.0245	0.0000	0.0245	0.0368	-0.0768	-0.0399	0.0431	-0.0784	-0.0353	0.0746	-0.0854	-0.0109
9	0.0245	0.0000	0.0245	0.0368	-0.0721	-0.0353	0.0492	-0.0735	-0.0243	0.0745	-0.0803	-0.0057
10	0.0245	0.0000	0.0245	0.0368	-0.0675	-0.0306	0.0492	-0.0689	-0.0196	0.0745	-0.0752	-0.0006
11	0.0184	0.0000	0.0184	0.0307	-0.0628	-0.0321	0.0492	-0.0642	-0.0150	0.0808	-0.0700	0.0107
12	0.0245	0.0000	0.0245	0.0368	-0.0582	-0.0213	0.0492	-0.0593	-0.0101	0.0745	-0.0649	0.0096
13	0.0245	0.0000	0.0245	0.0368	-0.0535	-0.0167	0.0431	-0.0547	-0.0116	0.0745	-0.0596	0.0150
14	0.0245	0.0000	0.0245	0.0368	-0.0488	-0.0120	0.0492	-0.0498	-0.0005	0.0745	-0.0544	0.0201
15	0.0184	0.0000	0.0184	0.0307	-0.0442	-0.0135	0.0492	-0.0451	0.0041	0.0807	-0.0493	0.0314
16	0.0245	0.0000	0.0245	0.0368	-0.0395	-0.0027	0.0492	-0.0405	0.0088	0.0745	-0.0442	0.0303
17	0.0245	0.0000	0.0245	0.0368	-0.0349	0.0020	0.0492	-0.0356	0.0136	0.0745	-0.0391	0.0354
18	0.0245	0.0000	0.0245	0.0368	-0.0302	0.0066	0.0431	-0.0309	0.0121	0.0745	-0.0337	0.0408
19	0.0184	0.0000	0.0184	0.0307	-0.0256	0.0051	0.0492	-0.0260	0.0232	0.0807	-0.0286	0.0521
20	0.0245	0.0000	0.0245	0.0368	-0.0209	0.0159	0.0492	-0.0214	0.0278	0.0745	-0.0235	0.0510
21	0.0245	0.0000	0.0245	0.0368	-0.0163	0.0206	0.0492	-0.0167	0.0325	0.0745	-0.0184	0.0561
22	0.0245	0.0000	0.0245	0.0368	-0.0116	0.0252	0.0492	-0.0119	0.0374	0.0745	-0.0133	0.0613
23	0.0184	0.0000	0.0184	0.0307	-0.0070	0.0237	0.0431	-0.0072	0.0359	0.0807	-0.0079	0.0728
24	0.0245	0.0000	0.0245	0.0368	-0.0023	0.0345	0.0492	-0.0023	0.0469	0.0745	-0.0028	0.0717
exit	0.0245	0.0000	0.0245	0.0368	0.0000	0.0368	0.0492	0.0000	0.0492	0.0745	0.0000	0.0745
TOTAL q _c	0.5758	0.0000	0.5758	0.8842	-1.3399	-0.4557	1.2002	-1.3680	-0.1678	1.9007	-1.4940	0.4067
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1304	-0.1465	-0.0161	0.1612	-0.1421	0.0191	0.2244	-0.0723	0.1521	0.2822	-0.0593	0.2229
2	0.1242	-0.1400	-0.0158	0.1674	-0.1351	0.0322	0.2181	-0.0678	0.1503	0.2821	-0.0551	0.2271
3	0.1304	-0.1337	-0.0033	0.1612	-0.1284	0.0328	0.2243	-0.0636	0.1607	0.2758	-0.0508	0.2250
4	0.1242	-0.1272	-0.0029	0.1674	-0.1214	0.0460	0.2243	-0.0592	0.1651	0.2820	-0.0466	0.2354
5	0.1304	-0.1209	0.0096	0.1611	-0.1144	0.0468	0.2242	-0.0550	0.1692	0.2820	-0.0424	0.2395
6	0.1242	-0.1143	0.0099	0.1673	-0.1074	0.0600	0.2180	-0.0506	0.1674	0.2819	-0.0382	0.2437
7	0.1304	-0.1078	0.0226	0.1611	-0.1004	0.0607	0.2242	-0.0464	0.1778	0.2756	-0.0338	0.2418
8	0.1242	-0.1015	0.0227	0.1673	-0.0936	0.0737	0.2241	-0.0419	0.1822	0.2818	-0.0296	0.2522
9	0.1304	-0.0950	0.0354	0.1611	-0.0866	0.0745	0.2179	-0.0377	0.1802	0.2818	-0.0254	0.2564
10	0.1242	-0.0887	0.0355	0.1673	-0.0796	0.0876	0.2241	-0.0333	0.1908	0.2817	-0.0212	0.2605
11	0.1304	-0.0822	0.0482	0.1611	-0.0726	0.0884	0.2241	-0.0291	0.1949	0.2754	-0.0170	0.2584
12	0.1241	-0.0756	0.0485	0.1672	-0.0656	0.1016	0.2240	-0.0247	0.1993	0.2816	-0.0128	0.2688
13	0.1303	-0.0694	0.0610	0.1610	-0.0589	0.1021	0.2178	-0.0205	0.1973	0.2816	-0.0086	0.2730
14	0.1241	-0.0628	0.0613	0.1672	-0.0519	0.1153	0.2240	-0.0161	0.2079	0.2815	-0.0044	0.2771
15	0.1303	-0.0565	0.0738	0.1610	-0.0449	0.1161	0.2239	-0.0119	0.2121	0.2752	-0.0002	0.2750
16	0.1241	-0.0500	0.0741	0.1672	-0.0379	0.1292	0.2239	-0.0074	0.2165	0.2815	0.0040	0.2854
17	0.1303	-0.0435	0.0868	0.1610	-0.0309	0.1300	0.2177	-0.0033	0.2144	0.2814	0.0081	0.2896
18	0.1241	-0.0372	0.0869	0.1671	-0.0242	0.1430	0.2239	0.0012	0.2250	0.2814	0.0123	0.2937
19	0.1303	-0.0307	0.0996	0.1609	-0.0172	0.1437	0.2238	0.0054	0.2292	0.2751	0.0167	0.2918
20	0.1241	-0.0244	0.0996	0.1671	-0.0102	0.1569	0.2176	0.0098	0.2274	0.2813	0.0209	0.3022
21	0.1303	-0.0179	0.1124	0.1609	-0.0033	0.1577	0.2238	0.0140	0.2377	0.2813	0.0251	0.3064
22	0.1241	-0.0114	0.1127	0.1671	0.0037	0.1708	0.2238	0.0184	0.2421	0.2812	0.0293	0.3105
23	0.1302	-0.0051	0.1251	0.1609	0.0105	0.1714	0.2237	0.0226	0.2463	0.2749	0.0335	0.3084
24	0.1240	0.0014	0.1254	0.1671	0.0174	0.1845	0.2175	0.0270	0.2445	0.2811	0.0377	0.3188
exit	0.1302	0.0000	0.1302	0.1609	0.0000	0.1609	0.2237	0.0000	0.2237	0.2811	0.0000	0.2811
TOTAL q _c	3.1839	-1.7410	1.4429	4.1001	-1.4952	2.6050	5.5567	-0.5426	5.0140	7.0026	-0.2578	6.7447
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3404	-0.0346	0.3058	0.3578	-0.0131	0.3448	0.3717	-0.0030	0.3687	0.3689	-0.0005	0.3684
2	0.3403	-0.0324	0.3078	0.3578	-0.0128	0.3449	0.3653	-0.0030	0.3623	0.3750	-0.0005	0.3746
3	0.3402	-0.0303	0.3099	0.3577	-0.0124	0.3453	0.3716	-0.0030	0.3685	0.3687	-0.0005	0.3682
4	0.3338	-0.0282	0.3056	0.3576	-0.0121	0.3454	0.3652	-0.0028	0.3624	0.3686	-0.0005	0.3681
5	0.3400	-0.0261	0.3139	0.3575	-0.0117	0.3458	0.3714	-0.0028	0.3686	0.3748	-0.0005	0.3743
6	0.3399	-0.0240	0.3159	0.3574	-0.0112	0.3462	0.3650	-0.0028	0.3622	0.3684	-0.0005	0.3679
7	0.3399	-0.0217	0.3182	0.3573	-0.0110	0.3463	0.3712	-0.0026	0.3686	0.3683	-0.0005	0.3679
8	0.3398	-0.0196	0.3202	0.3572	-0.0105	0.3467	0.3648	-0.0026	0.3622	0.3745	-0.0005	0.3740
9	0.3397	-0.0175	0.3222	0.3571	-0.0103	0.3469	0.3710	-0.0026	0.3684	0.3681	-0.0002	0.3679
10	0.3334	-0.0154	0.3180	0.3570	-0.0098	0.3473	0.3646	-0.0023	0.3623	0.3680	-0.0002	0.3678
11	0.3396	-0.0133	0.3263	0.3570	-0.0093	0.3476	0.3708	-0.0023	0.3685	0.3742	-0.0002	0.3739
12	0.3395	-0.0112	0.3283	0.3569	-0.0091	0.3478	0.3644	-0.0023	0.3621	0.3678	-0.0002	0.3676
13	0.3395	-0.0091	0.3304	0.3631	-0.0086	0.3545	0.3706	-0.0023	0.3683	0.3678	-0.0002	0.3675
14	0.3394	-0.0070	0.3324	0.3567	-0.0084	0.3484	0.3643	-0.0021	0.3622	0.3677	-0.0002	0.3675
15	0.3393	-0.0049	0.3344	0.3567	-0.0079	0.3488	0.3705	-0.0021	0.3684	0.3738	-0.0002	0.3736
16	0.3330	-0.0028	0.3302	0.3566	-0.0074	0.3492	0.3641	-0.0021	0.3620	0.3675	-0.0002	0.3673
17	0.3392	-0.0007	0.3385	0.3565	-0.0072	0.3493	0.3703	-0.0019	0.3685	0.3675	-0.0002	0.3672
18	0.3391	0.0014	0.3405	0.3565	-0.0067	0.3497	0.3640	-0.0019	0.3621	0.3736	-0.0002	0.3734
19	0.3391	0.0037	0.3428	0.3564	-0.0065	0.3499	0.3702	-0.0019	0.3683	0.3673	-0.0002	0.3671
20	0.3390	0.0058	0.3448	0.3563	-0.0060	0.3503	0.3638	-0.0016	0.3622	0.3672	-0.0002	0.3670
21	0.3390	0.0079	0.3469	0.3563	-0.0056	0.3507	0.3700	-0.0016	0.3684	0.3734	-0.0002	0.3732
22	0.3326	0.0100	0.3426	0.3562	-0.0053	0.3509	0.3637	-0.0016	0.3621	0.3671	0.0000	0.3671
23	0.3389	0.0121	0.3510	0.3562	-0.0049	0.3513	0.3699	-0.0016	0.3683	0.3670	0.0000	0.3670
24	0.3388	0.0142	0.3530	0.3561	-0.0046	0.3514	0.3636	-0.0014	0.3622	0.3732	0.0000	0.3732
exit	0.3388	0.0000	0.3388	0.3560	0.0000	0.3560	0.3698	0.0000	0.3698	0.3669	0.0000	0.3669
TOTAL q _c	8.4621	-0.2436	8.2185	8.9279	-0.2126	8.7153	9.1918	-0.0543	9.1375	9.2455	-0.0068	9.2388

Table M11: Coil Set Energy Balance for R3-60 at 7LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0096	0.0000	0.0096	0.0097	-0.0202	-0.0106	0.0195	-0.0982	-0.0787	0.0244	-0.0358	-0.0114
2	0.0096	0.0000	0.0096	0.0097	-0.0195	-0.0099	0.0195	-0.0940	-0.0745	0.0244	-0.0342	-0.0098
3	0.0048	0.0000	0.0048	0.0097	-0.0186	-0.0089	0.0195	-0.0898	-0.0703	0.0293	-0.0328	-0.0035
4	0.0096	0.0000	0.0096	0.0097	-0.0179	-0.0082	0.0195	-0.0856	-0.0661	0.0244	-0.0312	-0.0068
5	0.0096	0.0000	0.0096	0.0145	-0.0172	-0.0027	0.0195	-0.0814	-0.0619	0.0244	-0.0298	-0.0054
6	0.0096	0.0000	0.0096	0.0097	-0.0165	-0.0068	0.0195	-0.0772	-0.0578	0.0244	-0.0284	-0.0040
7	0.0096	0.0000	0.0096	0.0097	-0.0158	-0.0062	0.0146	-0.0730	-0.0584	0.0244	-0.0268	-0.0023
8	0.0048	0.0000	0.0048	0.0097	-0.0149	-0.0052	0.0195	-0.0689	-0.0494	0.0293	-0.0254	0.0039
9	0.0096	0.0000	0.0096	0.0097	-0.0142	-0.0045	0.0195	-0.0647	-0.0452	0.0244	-0.0237	0.0007
10	0.0096	0.0000	0.0096	0.0097	-0.0135	-0.0038	0.0195	-0.0605	-0.0410	0.0244	-0.0223	0.0021
11	0.0096	0.0000	0.0096	0.0097	-0.0128	-0.0031	0.0195	-0.0563	-0.0368	0.0244	-0.0209	0.0035
12	0.0096	0.0000	0.0096	0.0097	-0.0121	-0.0024	0.0195	-0.0521	-0.0326	0.0244	-0.0193	0.0051
13	0.0048	0.0000	0.0048	0.0145	-0.0112	0.0033	0.0195	-0.0479	-0.0284	0.0293	-0.0179	0.0114
14	0.0096	0.0000	0.0096	0.0097	-0.0105	-0.0008	0.0195	-0.0437	-0.0243	0.0244	-0.0163	0.0081
15	0.0096	0.0000	0.0096	0.0097	-0.0098	-0.0001	0.0195	-0.0395	-0.0201	0.0244	-0.0149	0.0095
16	0.0096	0.0000	0.0096	0.0097	-0.0091	0.0006	0.0195	-0.0354	-0.0159	0.0244	-0.0135	0.0109
17	0.0096	0.0000	0.0096	0.0097	-0.0084	0.0013	0.0195	-0.0312	-0.0117	0.0244	-0.0119	0.0125
18	0.0048	0.0000	0.0048	0.0097	-0.0074	0.0022	0.0195	-0.0270	-0.0075	0.0293	-0.0105	0.0188
19	0.0096	0.0000	0.0096	0.0097	-0.0067	0.0029	0.0146	-0.0228	-0.0082	0.0244	-0.0088	0.0156
20	0.0096	0.0000	0.0096	0.0097	-0.0060	0.0036	0.0195	-0.0186	0.0009	0.0244	-0.0074	0.0170
21	0.0096	0.0000	0.0096	0.0145	-0.0053	0.0091	0.0195	-0.0144	0.0050	0.0244	-0.0060	0.0184
22	0.0096	0.0000	0.0096	0.0097	-0.0047	0.0050	0.0195	-0.0102	0.0092	0.0244	-0.0044	0.0200
23	0.0048	0.0000	0.0048	0.0097	-0.0037	0.0059	0.0195	-0.0060	0.0134	0.0293	-0.0030	0.0263
24	0.0096	0.0000	0.0096	0.0097	-0.0030	0.0066	0.0195	-0.0019	0.0176	0.0244	-0.0014	0.0230
exit	0.0096	0.0000	0.0096	0.0097	0.0000	0.0097	0.0195	0.0000	0.0195	0.0244	0.0000	0.0244
TOTAL q _c	0.2168	0.0000	0.2168	0.2561	-0.2791	-0.0230	0.4770	-1.2003	-0.7232	0.6346	-0.4466	0.1880
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0595	-0.1429	-0.0834	0.0746	-0.0859	-0.0114	0.1277	-0.1079	0.0198	0.1680	-0.0564	0.1116
2	0.0546	-0.1369	-0.0823	0.0745	-0.0824	-0.0079	0.1277	-0.1028	0.0249	0.1680	-0.0525	0.1156
3	0.0595	-0.1308	-0.0713	0.0696	-0.0787	-0.0091	0.1277	-0.0974	0.0303	0.1729	-0.0487	0.1242
4	0.0595	-0.1250	-0.0655	0.0745	-0.0752	-0.0007	0.1277	-0.0923	0.0354	0.1680	-0.0450	0.1230
5	0.0546	-0.1189	-0.0644	0.0745	-0.0715	0.0031	0.1277	-0.0869	0.0408	0.1679	-0.0410	0.1269
6	0.0595	-0.1129	-0.0533	0.0745	-0.0677	0.0068	0.1276	-0.0818	0.0459	0.1679	-0.0373	0.1306
7	0.0595	-0.1068	-0.0473	0.0745	-0.0642	0.0103	0.1325	-0.0764	0.0561	0.1728	-0.0335	0.1393
8	0.0546	-0.1008	-0.0462	0.0696	-0.0605	0.0090	0.1276	-0.0713	0.0564	0.1679	-0.0296	0.1383
9	0.0595	-0.0947	-0.0352	0.0745	-0.0570	0.0175	0.1276	-0.0659	0.0617	0.1678	-0.0259	0.1420
10	0.0595	-0.0887	-0.0291	0.0745	-0.0533	0.0212	0.1276	-0.0605	0.0671	0.1678	-0.0221	0.1457
11	0.0546	-0.0826	-0.0280	0.0745	-0.0496	0.0249	0.1276	-0.0554	0.0722	0.1727	-0.0182	0.1546
12	0.0595	-0.0768	-0.0173	0.0745	-0.0461	0.0284	0.1276	-0.0501	0.0775	0.1678	-0.0144	0.1534
13	0.0595	-0.0707	-0.0112	0.0695	-0.0424	0.0272	0.1276	-0.0449	0.0826	0.1678	-0.0107	0.1571
14	0.0595	-0.0647	-0.0052	0.0745	-0.0389	0.0356	0.1275	-0.0396	0.0880	0.1677	-0.0070	0.1608
15	0.0546	-0.0586	-0.0041	0.0745	-0.0351	0.0394	0.1275	-0.0344	0.0931	0.1727	-0.0030	0.1696
16	0.0595	-0.0526	0.0069	0.0745	-0.0314	0.0431	0.1275	-0.0291	0.0984	0.1677	0.0007	0.1684
17	0.0595	-0.0465	0.0130	0.0745	-0.0279	0.0466	0.1275	-0.0237	0.1038	0.1677	0.0044	0.1721
18	0.0545	-0.0405	0.0141	0.0695	-0.0242	0.0453	0.1275	-0.0186	0.1089	0.1677	0.0084	0.1760
19	0.0595	-0.0347	0.0248	0.0745	-0.0207	0.0538	0.1324	-0.0133	0.1191	0.1726	0.0121	0.1847
20	0.0595	-0.0286	0.0309	0.0745	-0.0170	0.0575	0.1275	-0.0081	0.1193	0.1676	0.0158	0.1835
21	0.0545	-0.0226	0.0320	0.0745	-0.0133	0.0612	0.1275	-0.0028	0.1247	0.1676	0.0198	0.1874
22	0.0595	-0.0165	0.0430	0.0745	-0.0098	0.0647	0.1275	0.0023	0.1298	0.1676	0.0235	0.1911
23	0.0595	-0.0105	0.0490	0.0695	-0.0060	0.0635	0.1275	0.0077	0.1351	0.1725	0.0272	0.1997
24	0.0545	-0.0044	0.0501	0.0745	-0.0026	0.0719	0.1274	0.0128	0.1402	0.1676	0.0312	0.1987
exit	0.0595	0.0000	0.0595	0.0745	0.0000	0.0745	0.1274	0.0000	0.1274	0.1675	0.0000	0.1675
TOTAL q _c	1.4482	-1.7686	-0.3204	1.8379	-1.0613	0.7765	3.1988	-1.1403	2.0586	4.2239	-0.3022	3.9217
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2508	-0.0471	0.2037	0.2941	-0.0177	0.2763	0.3137	-0.0044	0.3093	0.3183	-0.0007	0.3176
2	0.2558	-0.0434	0.2124	0.2990	-0.0166	0.2824	0.3087	-0.0044	0.3042	0.3182	-0.0007	0.3175
3	0.2507	-0.0397	0.2110	0.2939	-0.0156	0.2783	0.3135	-0.0042	0.3093	0.3181	-0.0007	0.3174
4	0.2506	-0.0359	0.2147	0.2939	-0.0145	0.2794	0.3085	-0.0040	0.3045	0.3180	-0.0007	0.3173
5	0.2556	-0.0322	0.2234	0.2988	-0.0135	0.2852	0.3134	-0.0040	0.3094	0.3130	-0.0005	0.3125
6	0.2505	-0.0284	0.2221	0.2937	-0.0124	0.2813	0.3083	-0.0037	0.3046	0.3178	-0.0005	0.3174
7	0.2505	-0.0245	0.2260	0.2986	-0.0114	0.2872	0.3132	-0.0035	0.3097	0.3178	-0.0005	0.3173
8	0.2554	-0.0207	0.2347	0.2936	-0.0103	0.2833	0.3081	-0.0035	0.3046	0.3177	-0.0005	0.3172
9	0.2504	-0.0170	0.2334	0.2935	-0.0093	0.2842	0.3130	-0.0033	0.3098	0.3176	-0.0005	0.3171
10	0.2503	-0.0133	0.2371	0.2984	-0.0082	0.2902	0.3080	-0.0030	0.3049	0.3175	-0.0005	0.3170
11	0.2553	-0.0095	0.2458	0.2934	-0.0072	0.2861	0.3129	-0.0030	0.3098	0.3174	-0.0005	0.3169
12	0.2503	-0.0058	0.2444	0.2933	-0.0061	0.2872	0.3078	-0.0028	0.3050	0.3173	-0.0002	0.3171
13	0.2502	-0.0021	0.2481	0.2982	-0.0051	0.2931	0.3127	-0.0028	0.3099	0.3123	-0.0002	0.3121
14	0.2502	0.0016	0.2518	0.2932	-0.0040	0.2892	0.3077	-0.0026	0.3051	0.3172	-0.0002	0.3170
15	0.2551	0.0054	0.2605	0.2931	-0.0030	0.2901	0.3126	-0.0023	0.3103	0.3171	-0.0002	0.3169
16	0.2501	0.0091	0.2592	0.2980	-0.0019	0.2962	0.3076	-0.0023	0.3052	0.3171	-0.0002	0.3168
17	0.2500	0.0128	0.2628	0.2930	-0.0009	0.2921	0.3125	-0.0021	0.3104	0.3170	-0.0002	0.3168
18	0.2550	0.0165	0.2715	0.2929	0.0002	0.2932	0.3074	-0.0019	0.3056	0.3169	-0.0002	0.3167
19	0.2500	0.0205	0.2704	0.2979	0.0012	0.2990	0.3123	-0.0019	0.3105	0.3169	-0.0002	0.3166
20	0.2499	0.0242	0.2741	0.2928	0.0023	0.2952	0.3073	-0.0016	0.3057	0.3168	0.0000	0.3168
21	0.2549	0.0279	0.2828	0.2977	0.0033	0.3010	0.3122	-0.0016	0.3106	0.3118	0.0000	0.3118
22	0.2498	0.0316	0.2815	0.2927	0.0044	0.2972	0.3072	-0.0014	0.3058	0.3167	0.0000	0.3167
23	0.2498	0.0353	0.2851	0.2927	0.0053	0.2980	0.3121	-0.0012	0.3110	0.3166	0.0000	0.3166
24	0.2548	0.0390	0.2938	0.2976	0.0065	0.3041	0.3071	-0.0012	0.3059	0.3166	0.0000	0.3166
exit	0.2497	0.0000	0.2497	0.2926	0.0000	0.2926	0.3120	0.0000	0.3120	0.3165	0.0000	0.3165
TOTAL q _c	6.2957	-0.0958	6.1999	7.3765	-0.1344	7.2421	7.7600	-0.0667	7.6934	7.9182	-0.0079	7.9102

Table M12: Coil Set Energy Balance for R3-60 at 5.5LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0073	0.0000	0.0073	0.0072	-0.0358	-0.0286	0.0146	-0.0870	-0.0725	0.0218	-0.0512	-0.0295
2	0.0036	0.0000	0.0036	0.0072	-0.0342	-0.0270	0.0146	-0.0833	-0.0688	0.0218	-0.0491	-0.0274
3	0.0073	0.0000	0.0073	0.0109	-0.0328	-0.0219	0.0146	-0.0796	-0.0650	0.0181	-0.0468	-0.0287
4	0.0036	0.0000	0.0036	0.0072	-0.0312	-0.0239	0.0109	-0.0759	-0.0649	0.0218	-0.0447	-0.0229
5	0.0073	0.0000	0.0073	0.0072	-0.0298	-0.0225	0.0146	-0.0721	-0.0576	0.0218	-0.0424	-0.0206
6	0.0073	0.0000	0.0073	0.0072	-0.0284	-0.0211	0.0146	-0.0684	-0.0539	0.0218	-0.0400	-0.0183
7	0.0036	0.0000	0.0036	0.0109	-0.0268	-0.0159	0.0146	-0.0647	-0.0501	0.0181	-0.0379	-0.0198
8	0.0073	0.0000	0.0073	0.0072	-0.0254	-0.0181	0.0146	-0.0610	-0.0464	0.0217	-0.0356	-0.0139
9	0.0036	0.0000	0.0036	0.0072	-0.0237	-0.0165	0.0146	-0.0572	-0.0427	0.0217	-0.0335	-0.0118
10	0.0073	0.0000	0.0073	0.0072	-0.0223	-0.0151	0.0109	-0.0535	-0.0426	0.0217	-0.0312	-0.0094
11	0.0073	0.0000	0.0073	0.0109	-0.0209	-0.0101	0.0146	-0.0498	-0.0352	0.0181	-0.0289	-0.0107
12	0.0036	0.0000	0.0036	0.0072	-0.0193	-0.0121	0.0146	-0.0461	-0.0315	0.0217	-0.0268	-0.0050
13	0.0073	0.0000	0.0073	0.0072	-0.0179	-0.0107	0.0146	-0.0423	-0.0278	0.0217	-0.0244	-0.0027
14	0.0036	0.0000	0.0036	0.0072	-0.0163	-0.0090	0.0146	-0.0386	-0.0241	0.0217	-0.0223	-0.0006
15	0.0073	0.0000	0.0073	0.0109	-0.0149	-0.0040	0.0146	-0.0349	-0.0203	0.0181	-0.0200	-0.0019
16	0.0073	0.0000	0.0073	0.0072	-0.0135	-0.0062	0.0109	-0.0312	-0.0203	0.0217	-0.0177	0.0041
17	0.0036	0.0000	0.0036	0.0072	-0.0119	-0.0046	0.0146	-0.0275	-0.0129	0.0217	-0.0156	0.0062
18	0.0073	0.0000	0.0073	0.0072	-0.0105	-0.0032	0.0146	-0.0237	-0.0092	0.0217	-0.0133	0.0085
19	0.0036	0.0000	0.0036	0.0109	-0.0088	0.0020	0.0146	-0.0200	-0.0055	0.0181	-0.0112	0.0070
20	0.0073	0.0000	0.0073	0.0072	-0.0074	-0.0002	0.0146	-0.0163	-0.0017	0.0217	-0.0088	0.0129
21	0.0073	0.0000	0.0073	0.0072	-0.0060	0.0012	0.0146	-0.0126	0.0020	0.0217	-0.0065	0.0152
22	0.0036	0.0000	0.0036	0.0072	-0.0044	0.0028	0.0109	-0.0088	0.0021	0.0217	-0.0044	0.0173
23	0.0073	0.0000	0.0073	0.0109	-0.0030	0.0078	0.0146	-0.0051	0.0094	0.0181	-0.0021	0.0160
24	0.0036	0.0000	0.0036	0.0072	-0.0014	0.0059	0.0146	-0.0014	0.0132	0.0217	0.0000	0.0217
exit	0.0073	0.0000	0.0073	0.0072	0.0000	0.0072	0.0146	0.0000	0.0146	0.0217	0.0000	0.0217
TOTAL q _c	0.1452	0.0000	0.1452	0.2029	-0.4467	-0.2438	0.3493	-1.0611	-0.7118	0.5219	-0.6144	-0.0925
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0329	-0.0661	-0.0332	0.0439	-0.0724	-0.0286	0.0744	-0.0645	0.0099	0.1085	-0.0592	0.0493
2	0.0365	-0.0633	-0.0268	0.0439	-0.0692	-0.0253	0.0707	-0.0610	0.0096	0.1123	-0.0548	0.0575
3	0.0329	-0.0605	-0.0276	0.0475	-0.0659	-0.0184	0.0744	-0.0575	0.0168	0.1085	-0.0501	0.0584
4	0.0365	-0.0577	-0.0212	0.0439	-0.0626	-0.0188	0.0744	-0.0540	0.0203	0.1122	-0.0457	0.0666
5	0.0329	-0.0547	-0.0218	0.0439	-0.0594	-0.0155	0.0707	-0.0508	0.0199	0.1085	-0.0410	0.0675
6	0.0365	-0.0519	-0.0154	0.0439	-0.0561	-0.0123	0.0744	-0.0473	0.0271	0.1122	-0.0366	0.0756
7	0.0329	-0.0491	-0.0162	0.0475	-0.0528	-0.0053	0.0744	-0.0438	0.0306	0.1085	-0.0319	0.0765
8	0.0365	-0.0463	-0.0098	0.0438	-0.0496	-0.0057	0.0706	-0.0403	0.0303	0.1122	-0.0275	0.0847
9	0.0329	-0.0433	-0.0104	0.0438	-0.0463	-0.0025	0.0743	-0.0368	0.0376	0.1084	-0.0228	0.0856
10	0.0329	-0.0405	-0.0076	0.0438	-0.0431	0.0008	0.0743	-0.0333	0.0410	0.1084	-0.0184	0.0900
11	0.0365	-0.0377	-0.0012	0.0475	-0.0398	0.0077	0.0706	-0.0298	0.0408	0.1121	-0.0137	0.0984
12	0.0329	-0.0347	-0.0018	0.0438	-0.0365	0.0073	0.0743	-0.0263	0.0480	0.1084	-0.0093	0.0991
13	0.0365	-0.0319	0.0046	0.0438	-0.0333	0.0106	0.0743	-0.0230	0.0513	0.1121	-0.0047	0.1075
14	0.0329	-0.0291	0.0038	0.0438	-0.0300	0.0138	0.0743	-0.0196	0.0548	0.1084	-0.0002	0.1081
15	0.0365	-0.0263	0.0102	0.0475	-0.0268	0.0207	0.0706	-0.0161	0.0545	0.1121	0.0044	0.1165
16	0.0329	-0.0233	0.0096	0.0438	-0.0235	0.0203	0.0743	-0.0126	0.0617	0.1084	0.0088	0.1172
17	0.0329	-0.0205	0.0124	0.0438	-0.0202	0.0236	0.0743	-0.0091	0.0652	0.1083	0.0135	0.1218
18	0.0365	-0.0177	0.0188	0.0438	-0.0170	0.0268	0.0706	-0.0056	0.0650	0.1121	0.0179	0.1300
19	0.0329	-0.0149	0.0180	0.0475	-0.0137	0.0338	0.0743	-0.0021	0.0722	0.1083	0.0226	0.1309
20	0.0365	-0.0119	0.0247	0.0438	-0.0105	0.0334	0.0743	0.0014	0.0757	0.1120	0.0270	0.1390
21	0.0329	-0.0091	0.0238	0.0438	-0.0072	0.0366	0.0706	0.0047	0.0752	0.1083	0.0316	0.1399
22	0.0365	-0.0063	0.0302	0.0438	-0.0040	0.0399	0.0743	0.0081	0.0824	0.1120	0.0361	0.1481
23	0.0329	-0.0035	0.0294	0.0475	-0.0007	0.0468	0.0743	0.0116	0.0859	0.1083	0.0407	0.1490
24	0.0365	-0.0005	0.0361	0.0438	0.0026	0.0464	0.0706	0.0151	0.0857	0.1120	0.0451	0.1571
exit	0.0329	0.0000	0.0329	0.0438	0.0000	0.0438	0.0743	0.0000	0.0743	0.1083	0.0000	0.1083
TOTAL q _c	0.8621	-0.8007	0.0614	1.1179	-0.8381	0.2798	1.8285	-0.5925	1.2360	2.7508	-0.1682	2.5827
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1610	-0.0331	0.1279	0.2230	-0.0194	0.2036	0.2560	-0.0061	0.2499	0.2606	-0.0009	0.2597
2	0.1647	-0.0299	0.1349	0.2268	-0.0175	0.2093	0.2559	-0.0058	0.2501	0.2605	-0.0009	0.2596
3	0.1610	-0.0266	0.1344	0.2229	-0.0159	0.2070	0.2558	-0.0054	0.2505	0.2644	-0.0007	0.2637
4	0.1609	-0.0235	0.1374	0.2267	-0.0140	0.2127	0.2558	-0.0051	0.2506	0.2604	-0.0007	0.2597
5	0.1609	-0.0203	0.1406	0.2228	-0.0124	0.2104	0.2557	-0.0049	0.2508	0.2603	-0.0007	0.2596
6	0.1646	-0.0170	0.1476	0.2227	-0.0105	0.2122	0.2556	-0.0044	0.2512	0.2602	-0.0007	0.2595
7	0.1608	-0.0137	0.1471	0.2265	-0.0089	0.2177	0.2555	-0.0042	0.2513	0.2602	-0.0007	0.2595
8	0.1608	-0.0105	0.1503	0.2226	-0.0070	0.2156	0.2555	-0.0040	0.2515	0.2640	-0.0005	0.2635
9	0.1645	-0.0072	0.1573	0.2264	-0.0051	0.2213	0.2554	-0.0037	0.2517	0.2600	-0.0005	0.2595
10	0.1608	-0.0042	0.1566	0.2225	-0.0035	0.2190	0.2553	-0.0033	0.2521	0.2599	-0.0005	0.2595
11	0.1607	-0.0009	0.1598	0.2225	-0.0016	0.2209	0.2553	-0.0030	0.2522	0.2599	-0.0005	0.2594
12	0.1607	0.0023	0.1631	0.2263	0.0000	0.2263	0.2552	-0.0028	0.2524	0.2598	-0.0002	0.2596
13	0.1644	0.0056	0.1700	0.2224	0.0019	0.2243	0.2552	-0.0023	0.2528	0.2636	-0.0002	0.2634
14	0.1607	0.0088	0.1695	0.2262	0.0035	0.2297	0.2551	-0.0021	0.2530	0.2597	-0.0002	0.2595
15	0.1607	0.0121	0.1728	0.2223	0.0054	0.2277	0.2550	-0.0019	0.2532	0.2596	-0.0002	0.2594
16	0.1606	0.0151	0.1758	0.2223	0.0070	0.2292	0.2550	-0.0014	0.2536	0.2596	-0.0002	0.2593
17	0.1643	0.0184	0.1827	0.2261	0.0088	0.2349	0.2549	-0.0012	0.2538	0.2595	0.0000	0.2595
18	0.1606	0.0216	0.1822	0.2222	0.0107	0.2329	0.2549	-0.0009	0.2540	0.2633	0.0000	0.2633
19	0.1606	0.0249	0.1854	0.2260	0.0123	0.2383	0.2548	-0.0005	0.2544	0.2594	0.0000	0.2594
20	0.1643	0.0281	0.1924	0.2221	0.0142	0.2363	0.2548	-0.0002	0.2546	0.2594	0.0000	0.2594
21	0.1605	0.0314	0.1919	0.2221	0.0158	0.2379	0.2547	0.0000	0.2547	0.2593	0.0002	0.2595
22	0.1605	0.0344	0.1949	0.2259	0.0177	0.2435	0.2547	0.0005	0.2552	0.2593	0.0002	0.2595
23	0.1605	0.0377	0.1981	0.2220	0.0193	0.2413	0.2546	0.0007	0.2553	0.2631	0.0002	0.2633
24	0.1642	0.0409	0.2051	0.2258	0.0211	0.2469	0.2546	0.0009	0.2555	0.2592	0.0002	0.2594
exit	0.1604	0.0000	0.1604	0.2219	0.0000	0.2219	0.2545	0.0000	0.2545	0.2591	0.0000	0.2591
TOTAL q _c	4.0438	0.0944	4.1383	5.5988	0.0219	5.6208	6.3799	-0.0611	6.3188	6.5143	-0.0075	6.5069

Table M13: Coil Set Energy Balance for R4-36 at 14LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0000	0.0000	0.0000	0.0000	0.0067	0.0067	0.0000	-0.0079	-0.0079	0.0761	-0.2093	-0.1332
2	0.0064	0.0000	0.0064	0.0000	0.0059	0.0059	0.0000	-0.0079	-0.0079	0.0761	-0.1940	-0.1179
3	0.0000	0.0000	0.0000	0.0000	0.0047	0.0047	0.0000	-0.0079	-0.0079	0.0666	-0.1790	-0.1124
4	0.0064	0.0000	0.0064	0.0083	0.0035	0.0118	0.0094	-0.0079	0.0015	0.0761	-0.1641	-0.0880
5	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0000	-0.0079	-0.0079	0.0761	-0.1487	-0.0726
6	0.0000	0.0000	0.0000	0.0000	0.0016	0.0016	0.0000	-0.0079	-0.0079	0.0761	-0.1338	-0.0577
7	0.0064	0.0000	0.0064	0.0000	0.0004	0.0004	0.0000	-0.0079	-0.0079	0.0761	-0.1188	-0.0427
8	0.0000	0.0000	0.0000	0.0000	-0.0004	-0.0004	0.0000	-0.0079	-0.0079	0.0666	-0.1035	-0.0369
9	0.0064	0.0000	0.0064	0.0000	-0.0016	-0.0016	0.0000	-0.0079	-0.0079	0.0761	-0.0885	-0.0124
10	0.0000	0.0000	0.0000	0.0000	-0.0028	-0.0028	0.0000	-0.0079	-0.0079	0.0761	-0.0736	0.0025
11	0.0000	0.0000	0.0000	0.0000	-0.0035	-0.0035	0.0000	-0.0079	-0.0079	0.0761	-0.0582	0.0179
12	0.0064	0.0000	0.0064	0.0083	-0.0047	0.0035	0.0094	-0.0079	0.0015	0.0761	-0.0433	0.0328
13	0.0000	0.0000	0.0000	0.0000	-0.0059	-0.0059	0.0000	-0.0079	-0.0079	0.0666	-0.0283	0.0383
14	0.0064	0.0000	0.0064	0.0000	-0.0067	-0.0067	0.0000	-0.0079	-0.0079	0.0761	-0.0130	0.0631
exit	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0761	0.0000	0.0761
TOTAL q _c	0.0383	0.0000	0.0383	0.0165	0.0000	0.0165	0.0187	-0.1101	-0.0914	1.1131	-1.5561	-0.4429
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2391	-0.3123	-0.0732	0.3465	-0.2805	0.0660	0.5290	-0.2450	0.2840	0.5795	-0.1113	0.4682
2	0.2391	-0.2894	-0.0503	0.3369	-0.2596	0.0772	0.5288	-0.2296	0.2993	0.5793	-0.1077	0.4716
3	0.2391	-0.2670	-0.0279	0.3464	-0.2387	0.1077	0.5287	-0.2141	0.3146	0.5792	-0.1038	0.4754
4	0.2391	-0.2445	-0.0054	0.3368	-0.2178	0.1190	0.5286	-0.1987	0.3299	0.5694	-0.1002	0.4692
5	0.2391	-0.2216	0.0174	0.3464	-0.1969	0.1495	0.5284	-0.1833	0.3452	0.5789	-0.0962	0.4827
6	0.2390	-0.1992	0.0398	0.3463	-0.1760	0.1703	0.5283	-0.1679	0.3605	0.5787	-0.0923	0.4865
7	0.2390	-0.1767	0.0623	0.3367	-0.1551	0.1815	0.5282	-0.1525	0.3758	0.5786	-0.0887	0.4899
8	0.2390	-0.1539	0.0851	0.3462	-0.1342	0.2120	0.5377	-0.1375	0.4003	0.5784	-0.0847	0.4937
9	0.2390	-0.1314	0.1075	0.3366	-0.1134	0.2232	0.5280	-0.1221	0.4059	0.5783	-0.0812	0.4972
10	0.2389	-0.1090	0.1299	0.3461	-0.0925	0.2537	0.5279	-0.1067	0.4212	0.5782	-0.0772	0.5010
11	0.2389	-0.0862	0.1528	0.3461	-0.0716	0.2745	0.5278	-0.0913	0.4365	0.5781	-0.0732	0.5048
12	0.2389	-0.0637	0.1752	0.3364	-0.0508	0.2857	0.5277	-0.0760	0.4518	0.5683	-0.0697	0.4986
13	0.2389	-0.0413	0.1976	0.3460	-0.0299	0.3161	0.5276	-0.0606	0.4670	0.5779	-0.0657	0.5121
14	0.2389	-0.0185	0.2204	0.3364	-0.0090	0.3273	0.5275	-0.0452	0.4823	0.5777	-0.0622	0.5155
exit	0.2389	0.0000	0.2389	0.3459	0.0000	0.3459	0.5274	0.0000	0.5274	0.5776	0.0000	0.5776
TOTAL q _c	3.5848	-2.3147	1.2701	5.1358	-2.0261	3.1097	7.9319	-2.0304	5.9015	8.6582	-1.2141	7.4441
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.6018	-0.0498	0.5521	0.5881	-0.0170	0.5711	0.5839	-0.0028	0.5811	0.5915	-0.0004	0.5911
2	0.6017	-0.0494	0.5523	0.5879	-0.0174	0.5706	0.5837	-0.0028	0.5810	0.5914	-0.0004	0.5910
3	0.5917	-0.0490	0.5427	0.5878	-0.0178	0.5700	0.5933	-0.0024	0.5909	0.5912	-0.0004	0.5908
4	0.6014	-0.0485	0.5528	0.5876	-0.0182	0.5695	0.5834	-0.0024	0.5811	0.5911	-0.0004	0.5907
5	0.6012	-0.0481	0.5531	0.5875	-0.0186	0.5689	0.5833	-0.0024	0.5809	0.5909	-0.0004	0.5905
6	0.6010	-0.0477	0.5533	0.5873	-0.0189	0.5684	0.5831	-0.0024	0.5808	0.5907	-0.0004	0.5903
7	0.6009	-0.0473	0.5535	0.5872	-0.0193	0.5678	0.5830	-0.0020	0.5810	0.5906	-0.0004	0.5902
8	0.5909	-0.0473	0.5436	0.5771	-0.0197	0.5574	0.5925	-0.0020	0.5906	0.5807	-0.0004	0.5803
9	0.6005	-0.0469	0.5536	0.5869	-0.0201	0.5668	0.5827	-0.0020	0.5807	0.5903	0.0000	0.5903
10	0.6004	-0.0465	0.5539	0.5867	-0.0205	0.5662	0.5825	-0.0020	0.5805	0.5901	0.0000	0.5901
11	0.6003	-0.0461	0.5542	0.5866	-0.0209	0.5657	0.5824	-0.0016	0.5808	0.5899	0.0000	0.5899
12	0.6002	-0.0457	0.5545	0.5864	-0.0213	0.5652	0.5822	-0.0016	0.5806	0.5898	0.0000	0.5898
13	0.5902	-0.0453	0.5449	0.5863	-0.0217	0.5647	0.5918	-0.0016	0.5902	0.5897	0.0000	0.5897
14	0.5999	-0.0449	0.5550	0.5862	-0.0221	0.5641	0.5820	-0.0016	0.5804	0.5896	0.0000	0.5896
exit	0.5998	0.0000	0.5998	0.5861	0.0000	0.5861	0.5819	0.0000	0.5819	0.5894	0.0000	0.5894
TOTAL q _c	8.9817	-0.6625	8.3192	8.7957	-0.2733	8.5224	8.7717	-0.0292	8.7425	8.8469	-0.0032	8.8437

Table M14: Coil Set Energy Balance for R4-36 at 12LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0082	0.0000	0.0082	0.0492	-0.2750	-0.2258	0.0904	-0.2310	-0.1406	0.2053	-0.3784	-0.1731
2	0.0163	0.0000	0.0163	0.0574	-0.2553	-0.1979	0.0822	-0.2145	-0.1323	0.1971	-0.3508	-0.1537
3	0.0082	0.0000	0.0082	0.0492	-0.2353	-0.1860	0.0904	-0.1975	-0.1072	0.2053	-0.3236	-0.1183
4	0.0163	0.0000	0.0163	0.0574	-0.2152	-0.1577	0.0904	-0.1806	-0.0902	0.1971	-0.2964	-0.0993
5	0.0082	0.0000	0.0082	0.0492	-0.1955	-0.1463	0.0904	-0.1641	-0.0737	0.2053	-0.2688	-0.0636
6	0.0082	0.0000	0.0082	0.0574	-0.1754	-0.1180	0.0821	-0.1471	-0.0650	0.2053	-0.2417	-0.0364
7	0.0163	0.0000	0.0163	0.0492	-0.1554	-0.1061	0.0903	-0.1302	-0.0399	0.1970	-0.2145	-0.0175
8	0.0082	0.0000	0.0082	0.0574	-0.1357	-0.0783	0.0903	-0.1137	-0.0233	0.2052	-0.1869	0.0183
9	0.0163	0.0000	0.0163	0.0492	-0.1156	-0.0664	0.0903	-0.0968	-0.0064	0.1970	-0.1598	0.0372
10	0.0082	0.0000	0.0082	0.0574	-0.0956	-0.0381	0.0821	-0.0799	0.0023	0.2052	-0.1326	0.0726
11	0.0082	0.0000	0.0082	0.0492	-0.0759	-0.0267	0.0903	-0.0633	0.0270	0.2052	-0.1050	0.1001
12	0.0163	0.0000	0.0163	0.0574	-0.0559	0.0016	0.0903	-0.0464	0.0439	0.1969	-0.0779	0.1191
13	0.0082	0.0000	0.0082	0.0492	-0.0358	0.0134	0.0903	-0.0295	0.0608	0.2051	-0.0507	0.1544
14	0.0163	0.0000	0.0163	0.0574	-0.0161	0.0413	0.0821	-0.0130	0.0691	0.1969	-0.0232	0.1737
exit	0.0082	0.0000	0.0082	0.0492	0.0000	0.0492	0.0903	0.0000	0.0903	0.2051	0.0000	0.2051
TOTAL q _c	0.1716	0.0000	0.1716	0.7959	-2.0377	-1.2418	1.3223	-1.7075	-0.3852	3.0291	-2.8104	0.2187
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3373	-0.2829	0.0544	0.3990	-0.1663	0.2327	0.4750	-0.1258	0.3492	0.5293	-0.1085	0.4207
2	0.3373	-0.2612	0.0760	0.3906	-0.1537	0.2369	0.4832	-0.1179	0.3653	0.5291	-0.1038	0.4253
3	0.3372	-0.2395	0.0977	0.3989	-0.1407	0.2582	0.4747	-0.1104	0.3644	0.5290	-0.0994	0.4296
4	0.3454	-0.2178	0.1276	0.3988	-0.1276	0.2712	0.4830	-0.1025	0.3805	0.5372	-0.0947	0.4426
5	0.3371	-0.1961	0.1410	0.3904	-0.1150	0.2754	0.4745	-0.0950	0.3795	0.5287	-0.0903	0.4384
6	0.3371	-0.1744	0.1626	0.3987	-0.1020	0.2967	0.4744	-0.0871	0.3873	0.5285	-0.0855	0.4430
7	0.3370	-0.1528	0.1843	0.3986	-0.0890	0.3096	0.4826	-0.0796	0.4031	0.5284	-0.0812	0.4472
8	0.3370	-0.1307	0.2063	0.3903	-0.0764	0.3139	0.4742	-0.0717	0.4026	0.5283	-0.0764	0.4518
9	0.3369	-0.1090	0.2279	0.3985	-0.0634	0.3351	0.4825	-0.0642	0.4183	0.5282	-0.0721	0.4561
10	0.3369	-0.0874	0.2495	0.3984	-0.0504	0.3480	0.4740	-0.0563	0.4177	0.5280	-0.0673	0.4607
11	0.3368	-0.0657	0.2711	0.3901	-0.0378	0.3523	0.4740	-0.0488	0.4251	0.5279	-0.0630	0.4649
12	0.3450	-0.0441	0.3009	0.3983	-0.0248	0.3735	0.4822	-0.0409	0.4412	0.5362	-0.0583	0.4779
13	0.3367	-0.0224	0.3143	0.3982	-0.0118	0.3864	0.4738	-0.0334	0.4403	0.5277	-0.0539	0.4738
14	0.3367	-0.0008	0.3359	0.3899	0.0008	0.3907	0.4820	-0.0256	0.4564	0.5276	-0.0492	0.4784
exit	0.3366	0.0000	0.3366	0.3981	0.0000	0.3981	0.4736	0.0000	0.4736	0.5275	0.0000	0.5275
TOTAL q _c	5.0710	-1.9849	3.0861	5.9369	-1.1581	4.7788	7.1637	-1.0591	6.1045	7.9415	-1.1036	6.8379
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.5339	-0.0426	0.4912	0.5279	-0.0166	0.5113	0.5355	-0.0032	0.5324	0.5400	-0.0004	0.5396
2	0.5421	-0.0422	0.4998	0.5278	-0.0166	0.5112	0.5354	-0.0032	0.5322	0.5399	-0.0004	0.5395
3	0.5336	-0.0418	0.4918	0.5277	-0.0170	0.5107	0.5352	-0.0032	0.5321	0.5397	-0.0004	0.5393
4	0.5334	-0.0410	0.4924	0.5359	-0.0170	0.5189	0.5267	-0.0028	0.5239	0.5396	-0.0004	0.5392
5	0.5333	-0.0406	0.4927	0.5274	-0.0174	0.5100	0.5349	-0.0028	0.5322	0.5394	-0.0004	0.5390
6	0.5415	-0.0402	0.5012	0.5272	-0.0174	0.5099	0.5348	-0.0028	0.5320	0.5393	-0.0004	0.5389
7	0.5330	-0.0398	0.4932	0.5271	-0.0177	0.5093	0.5346	-0.0028	0.5319	0.5391	-0.0004	0.5387
8	0.5328	-0.0394	0.4934	0.5269	-0.0181	0.5088	0.5345	-0.0028	0.5317	0.5390	-0.0004	0.5386
9	0.5327	-0.0390	0.4937	0.5268	-0.0181	0.5086	0.5343	-0.0028	0.5316	0.5388	-0.0004	0.5384
10	0.5409	-0.0386	0.5023	0.5266	-0.0185	0.5081	0.5342	-0.0028	0.5314	0.5387	-0.0004	0.5383
11	0.5325	-0.0382	0.4943	0.5265	-0.0185	0.5080	0.5340	-0.0024	0.5317	0.5385	-0.0004	0.5381
12	0.5324	-0.0374	0.4950	0.5348	-0.0189	0.5159	0.5256	-0.0024	0.5232	0.5384	-0.0004	0.5380
13	0.5322	-0.0370	0.4952	0.5263	-0.0189	0.5074	0.5338	-0.0024	0.5314	0.5383	-0.0004	0.5379
14	0.5404	-0.0366	0.5038	0.5262	-0.0193	0.5069	0.5337	-0.0024	0.5313	0.5382	-0.0004	0.5378
exit	0.5320	0.0000	0.5320	0.5261	0.0000	0.5261	0.5336	0.0000	0.5336	0.5381	0.0000	0.5381
TOTAL q _c	8.0268	-0.5547	7.4721	7.9211	-0.2500	7.6711	8.0008	-0.0383	7.9626	8.0848	-0.0055	8.0793

Table M15: Coil Set Energy Balance for R4-36 at 10LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0000	0.0000	0.0000	0.0000	-0.0075	-0.0075	0.0000	-0.0075	-0.0075	0.0475	-0.1885	-0.1409
2	0.0000	0.0000	0.0000	0.0000	-0.0067	-0.0067	0.0067	-0.0067	0.0000	0.0543	-0.1747	-0.1204
3	0.0000	0.0000	0.0000	0.0000	-0.0063	-0.0063	0.0000	-0.0063	-0.0063	0.0475	-0.1605	-0.1130
4	0.0000	0.0000	0.0000	0.0067	-0.0059	0.0008	0.0000	-0.0059	-0.0059	0.0543	-0.1464	-0.0921
5	0.0000	0.0000	0.0000	0.0000	-0.0051	-0.0051	0.0000	-0.0051	-0.0051	0.0475	-0.1326	-0.0851
6	0.0000	0.0000	0.0000	0.0000	-0.0047	-0.0047	0.0067	-0.0047	0.0020	0.0475	-0.1184	-0.0709
7	0.0000	0.0000	0.0000	0.0000	-0.0043	-0.0043	0.0000	-0.0043	-0.0043	0.0543	-0.1042	-0.0499
8	0.0000	0.0000	0.0000	0.0000	-0.0035	-0.0035	0.0000	-0.0035	-0.0035	0.0475	-0.0905	-0.0430
9	0.0000	0.0000	0.0000	0.0000	-0.0031	-0.0031	0.0000	-0.0031	-0.0031	0.0543	-0.0763	-0.0220
10	0.0000	0.0000	0.0000	0.0000	-0.0028	-0.0028	0.0067	-0.0028	0.0040	0.0475	-0.0622	-0.0146
11	0.0000	0.0000	0.0000	0.0000	-0.0020	-0.0020	0.0000	-0.0020	-0.0020	0.0475	-0.0484	-0.0009
12	0.0000	0.0000	0.0000	0.0067	-0.0016	0.0051	0.0000	-0.0016	-0.0016	0.0543	-0.0342	0.0201
13	0.0000	0.0000	0.0000	0.0000	-0.0012	-0.0012	0.0000	-0.0012	-0.0012	0.0475	-0.0201	0.0274
14	0.0000	0.0000	0.0000	0.0000	-0.0004	-0.0004	0.0067	-0.0004	0.0063	0.0543	-0.0063	0.0480
exit	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0475	0.0000	0.0475
TOTAL q _c	0.0000	0.0000	0.0000	0.0134	-0.0551	-0.0417	0.0269	-0.0551	-0.0282	0.7534	-1.3632	-0.6098
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1574	-0.2811	-0.1238	0.2055	-0.1867	0.0188	0.3338	-0.1821	0.1517	0.4131	-0.1215	0.2916
2	0.1642	-0.2602	-0.0960	0.2124	-0.1725	0.0399	0.3407	-0.1683	0.1724	0.4200	-0.1124	0.3076
3	0.1573	-0.2394	-0.0820	0.2055	-0.1583	0.0472	0.3337	-0.1541	0.1796	0.4129	-0.1037	0.3092
4	0.1573	-0.2185	-0.0611	0.2123	-0.1441	0.0682	0.3336	-0.1403	0.1934	0.4198	-0.0946	0.3252
5	0.1573	-0.1976	-0.0403	0.2055	-0.1299	0.0755	0.3336	-0.1261	0.2075	0.4127	-0.0859	0.3268
6	0.1641	-0.1767	-0.0126	0.2123	-0.1157	0.0965	0.3405	-0.1119	0.2286	0.4196	-0.0772	0.3423
7	0.1573	-0.1558	0.0014	0.2054	-0.1016	0.1039	0.3335	-0.0981	0.2354	0.4125	-0.0681	0.3443
8	0.1573	-0.1354	0.0219	0.2122	-0.0874	0.1249	0.3334	-0.0839	0.2496	0.4194	-0.0595	0.3599
9	0.1573	-0.1145	0.0428	0.2054	-0.0732	0.1322	0.3334	-0.0701	0.2633	0.4123	-0.0504	0.3619
10	0.1641	-0.0936	0.0705	0.2122	-0.0590	0.1532	0.3403	-0.0559	0.2844	0.4192	-0.0417	0.3775
11	0.1572	-0.0728	0.0845	0.2053	-0.0449	0.1605	0.3333	-0.0417	0.2915	0.4122	-0.0331	0.3791
12	0.1572	-0.0519	0.1053	0.2122	-0.0307	0.1815	0.3332	-0.0279	0.3053	0.4191	-0.0240	0.3950
13	0.1572	-0.0311	0.1261	0.2053	-0.0165	0.1888	0.3332	-0.0138	0.3194	0.4120	-0.0153	0.3966
14	0.1640	-0.0102	0.1538	0.2121	-0.0024	0.2098	0.3400	0.0000	0.3400	0.4189	-0.0063	0.4126
exit	0.1572	0.0000	0.1572	0.2052	0.0000	0.2052	0.3331	0.0000	0.3331	0.4118	0.0000	0.4118
TOTAL q _c	2.3866	-2.0389	0.3477	3.1288	-1.3229	1.8060	5.0292	-1.2740	3.7553	6.2353	-0.8938	5.3415
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.4750	-0.0596	0.4154	0.4729	-0.0245	0.4484	0.4814	-0.0047	0.4767	0.4889	-0.0008	0.4881
2	0.4679	-0.0564	0.4114	0.4797	-0.0241	0.4556	0.4813	-0.0047	0.4765	0.4888	-0.0008	0.4880
3	0.4747	-0.0533	0.4215	0.4726	-0.0241	0.4485	0.4811	-0.0047	0.4764	0.4886	-0.0004	0.4882
4	0.4676	-0.0497	0.4179	0.4794	-0.0237	0.4557	0.4810	-0.0047	0.4762	0.4815	-0.0004	0.4811
5	0.4744	-0.0465	0.4279	0.4723	-0.0237	0.4486	0.4808	-0.0047	0.4761	0.4883	-0.0004	0.4879
6	0.4743	-0.0434	0.4309	0.4791	-0.0233	0.4558	0.4807	-0.0047	0.4759	0.4882	-0.0004	0.4878
7	0.4672	-0.0402	0.4270	0.4720	-0.0233	0.4488	0.4805	-0.0047	0.4758	0.4880	-0.0004	0.4876
8	0.4740	-0.0370	0.4370	0.4788	-0.0233	0.4556	0.4873	-0.0043	0.4830	0.4879	-0.0004	0.4875
9	0.4670	-0.0339	0.4331	0.4718	-0.0229	0.4489	0.4802	-0.0043	0.4759	0.4877	-0.0004	0.4873
10	0.4738	-0.0307	0.4431	0.4786	-0.0228	0.4557	0.4801	-0.0043	0.4758	0.4876	-0.0004	0.4872
11	0.4737	-0.0276	0.4462	0.4715	-0.0224	0.4491	0.4800	-0.0043	0.4757	0.4875	-0.0004	0.4871
12	0.4666	-0.0240	0.4426	0.4784	-0.0224	0.4559	0.4799	-0.0043	0.4756	0.4804	-0.0004	0.4800
13	0.4735	-0.0209	0.4526	0.4713	-0.0220	0.4493	0.4798	-0.0043	0.4754	0.4872	-0.0004	0.4868
14	0.4664	-0.0177	0.4487	0.4781	-0.0220	0.4561	0.4797	-0.0043	0.4753	0.4871	-0.0004	0.4867
exit	0.4733	0.0000	0.4733	0.4711	0.0000	0.4711	0.4795	0.0000	0.4795	0.4870	0.0000	0.4870
TOTAL q _c	7.0695	-0.5408	6.5287	7.1276	-0.3245	6.8032	7.2134	-0.0635	7.1499	7.3046	-0.0063	7.2982

Table M16: Coil Set Energy Balance for R4-36 at 9LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0124	0.0000	0.0124	0.0186	-0.0767	-0.0581	0.0564	-0.3006	-0.2442	0.0882	-0.1433	-0.0550
2	0.0062	0.0000	0.0062	0.0186	-0.0712	-0.0526	0.0501	-0.2786	-0.2284	0.0882	-0.1326	-0.0444
3	0.0124	0.0000	0.0124	0.0186	-0.0653	-0.0467	0.0564	-0.2565	-0.2001	0.0882	-0.1224	-0.0341
4	0.0124	0.0000	0.0124	0.0248	-0.0594	-0.0346	0.0564	-0.2345	-0.1781	0.0882	-0.1121	-0.0239
5	0.0062	0.0000	0.0062	0.0186	-0.0539	-0.0353	0.0564	-0.2124	-0.1560	0.0882	-0.1015	-0.0133
6	0.0124	0.0000	0.0124	0.0186	-0.0480	-0.0294	0.0501	-0.1904	-0.1403	0.0882	-0.0913	-0.0031
7	0.0124	0.0000	0.0124	0.0186	-0.0421	-0.0235	0.0564	-0.1684	-0.1120	0.0882	-0.0810	0.0072
8	0.0062	0.0000	0.0062	0.0186	-0.0366	-0.0180	0.0564	-0.1463	-0.0899	0.0882	-0.0704	0.0178
9	0.0124	0.0000	0.0124	0.0186	-0.0307	-0.0121	0.0564	-0.1243	-0.0679	0.0882	-0.0602	0.0280
10	0.0124	0.0000	0.0124	0.0186	-0.0248	-0.0062	0.0501	-0.1023	-0.0522	0.0882	-0.0500	0.0382
11	0.0062	0.0000	0.0062	0.0186	-0.0193	-0.0006	0.0564	-0.0802	-0.0239	0.0882	-0.0393	0.0489
12	0.0124	0.0000	0.0124	0.0248	-0.0134	0.0115	0.0564	-0.0582	-0.0018	0.0882	-0.0291	0.0591
13	0.0124	0.0000	0.0124	0.0186	-0.0075	0.0112	0.0564	-0.0362	0.0202	0.0882	-0.0189	0.0693
14	0.0062	0.0000	0.0062	0.0186	-0.0020	0.0167	0.0501	-0.0142	0.0360	0.0882	-0.0083	0.0799
exit	0.0124	0.0000	0.0124	0.0186	0.0000	0.0186	0.0564	0.0000	0.0564	0.0882	0.0000	0.0882
TOTAL q _c	0.1547	0.0000	0.1547	0.2918	-0.5507	-0.2588	0.8208	-2.2031	-1.3823	1.3233	-1.0604	0.2628
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.1647	-0.2268	-0.0621	0.2091	-0.1706	0.0386	0.3203	-0.1861	0.1342	0.3633	-0.0939	0.2694
2	0.1710	-0.2103	-0.0392	0.2028	-0.1583	0.0444	0.3266	-0.1723	0.1543	0.3696	-0.0883	0.2812
3	0.1647	-0.1941	-0.0294	0.2091	-0.1457	0.0634	0.3201	-0.1580	0.1621	0.3631	-0.0828	0.2803
4	0.1647	-0.1779	-0.0133	0.2090	-0.1331	0.0759	0.3265	-0.1442	0.1823	0.3694	-0.0773	0.2921
5	0.1710	-0.1618	0.0092	0.2027	-0.1209	0.0818	0.3200	-0.1300	0.1900	0.3629	-0.0717	0.2912
6	0.1646	-0.1456	0.0190	0.2090	-0.1083	0.1007	0.3264	-0.1158	0.2105	0.3692	-0.0662	0.3030
7	0.1646	-0.1295	0.0351	0.2090	-0.0957	0.1133	0.3199	-0.1020	0.2179	0.3628	-0.0607	0.3021
8	0.1709	-0.1133	0.0576	0.2026	-0.0834	0.1192	0.3262	-0.0878	0.2384	0.3691	-0.0551	0.3139
9	0.1646	-0.0972	0.0674	0.2089	-0.0708	0.1381	0.3198	-0.0740	0.2458	0.3627	-0.0496	0.3130
10	0.1646	-0.0811	0.0835	0.2089	-0.0582	0.1507	0.3261	-0.0598	0.2663	0.3689	-0.0441	0.3248
11	0.1709	-0.0645	0.1064	0.2025	-0.0460	0.1565	0.3197	-0.0457	0.2740	0.3625	-0.0386	0.3239
12	0.1645	-0.0484	0.1162	0.2089	-0.0334	0.1754	0.3260	-0.0319	0.2941	0.3688	-0.0331	0.3357
13	0.1645	-0.0323	0.1323	0.2088	-0.0208	0.1880	0.3196	-0.0177	0.3019	0.3624	-0.0275	0.3348
14	0.1708	-0.0161	0.1547	0.2025	-0.0087	0.1938	0.3259	-0.0039	0.3220	0.3687	-0.0220	0.3466
exit	0.1645	0.0000	0.1645	0.2088	0.0000	0.2088	0.3195	0.0000	0.3195	0.3622	0.0000	0.3622
TOTAL q _c	2.5007	-1.6989	0.8018	3.1026	-1.2540	1.8486	4.8425	-1.3292	3.5133	5.4856	-0.8109	4.6747
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.3985	-0.0675	0.3310	0.4506	-0.0209	0.4297	0.4619	-0.0051	0.4568	0.4672	-0.0008	0.4664
2	0.3984	-0.0659	0.3325	0.4505	-0.0190	0.4315	0.4618	-0.0051	0.4566	0.4671	-0.0008	0.4663
3	0.3983	-0.0639	0.3344	0.4503	-0.0174	0.4330	0.4616	-0.0051	0.4565	0.4669	-0.0008	0.4661
4	0.3982	-0.0623	0.3359	0.4502	-0.0154	0.4348	0.4551	-0.0047	0.4504	0.4731	-0.0004	0.4727
5	0.3981	-0.0603	0.3377	0.4501	-0.0138	0.4362	0.4613	-0.0047	0.4566	0.4666	-0.0004	0.4662
6	0.3980	-0.0587	0.3392	0.4499	-0.0118	0.4381	0.4612	-0.0043	0.4568	0.4665	-0.0004	0.4661
7	0.3979	-0.0568	0.3411	0.4498	-0.0102	0.4395	0.4610	-0.0043	0.4567	0.4663	-0.0004	0.4659
8	0.3978	-0.0552	0.3426	0.4560	-0.0083	0.4477	0.4609	-0.0043	0.4565	0.4662	-0.0004	0.4658
9	0.3977	-0.0532	0.3445	0.4495	-0.0067	0.4428	0.4607	-0.0039	0.4568	0.4660	-0.0004	0.4656
10	0.3976	-0.0516	0.3460	0.4494	-0.0047	0.4447	0.4606	-0.0039	0.4567	0.4659	-0.0004	0.4655
11	0.3975	-0.0496	0.3479	0.4493	-0.0032	0.4461	0.4605	-0.0039	0.4566	0.4658	-0.0004	0.4654
12	0.3974	-0.0480	0.3494	0.4492	-0.0012	0.4480	0.4541	-0.0035	0.4505	0.4720	0.0000	0.4720
13	0.3973	-0.0461	0.3513	0.4491	0.0004	0.4495	0.4603	-0.0035	0.4567	0.4656	0.0000	0.4656
14	0.3972	-0.0445	0.3528	0.4490	0.0024	0.4513	0.4602	-0.0035	0.4566	0.4654	0.0000	0.4654
exit	0.3972	0.0000	0.3972	0.4489	0.0000	0.4489	0.4600	0.0000	0.4600	0.4653	0.0000	0.4653
TOTAL q _c	5.9669	-0.7836	5.1833	6.7516	-0.1298	6.6218	6.9012	-0.0603	6.8409	7.0060	-0.0055	7.0004

Table M17: Coil Set Energy Balance for R4-36 at 7LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0000	-0.0035	-0.0035	0.0231	-0.1298	-0.1067
2	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0000	-0.0035	-0.0035	0.0231	-0.1200	-0.0969
3	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	0.0046	-0.0031	0.0014	0.0277	-0.1102	-0.0824
4	0.0000	0.0000	0.0000	0.0045	0.0012	0.0057	0.0000	-0.0028	-0.0028	0.0231	-0.1003	-0.0772
5	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0000	-0.0028	-0.0028	0.0231	-0.0905	-0.0674
6	0.0000	0.0000	0.0000	0.0000	0.0016	0.0016	0.0000	-0.0024	-0.0024	0.0231	-0.0806	-0.0575
7	0.0000	0.0000	0.0000	0.0000	0.0020	0.0020	0.0000	-0.0020	-0.0020	0.0231	-0.0708	-0.0477
8	0.0045	0.0000	0.0045	0.0000	0.0020	0.0020	0.0046	-0.0020	0.0026	0.0277	-0.0610	-0.0332
9	0.0000	0.0000	0.0000	0.0000	0.0024	0.0024	0.0000	-0.0016	-0.0016	0.0231	-0.0511	-0.0280
10	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0000	-0.0012	-0.0012	0.0231	-0.0413	-0.0182
11	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0000	-0.0012	-0.0012	0.0231	-0.0315	-0.0083
12	0.0000	0.0000	0.0000	0.0045	0.0031	0.0077	0.0000	-0.0008	-0.0008	0.0231	-0.0216	0.0015
13	0.0000	0.0000	0.0000	0.0000	0.0035	0.0035	0.0046	-0.0004	0.0042	0.0277	-0.0118	0.0159
14	0.0000	0.0000	0.0000	0.0000	0.0035	0.0035	0.0000	-0.0004	-0.0004	0.0231	-0.0020	0.0212
exit	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0231	0.0000	0.0231
TOTAL q _c	0.0045	0.0000	0.0045	0.0091	0.0275	0.0366	0.0138	-0.0275	-0.0137	0.3607	-0.9225	-0.5618
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0706	-0.1783	-0.1077	0.0903	-0.1043	-0.0140	0.1735	-0.1639	0.0096	0.2376	-0.1167	0.1210
2	0.0753	-0.1649	-0.0897	0.0951	-0.0964	-0.0014	0.1783	-0.1505	0.0278	0.2424	-0.1064	0.1360
3	0.0705	-0.1515	-0.0810	0.0903	-0.0886	0.0017	0.1735	-0.1371	0.0364	0.2376	-0.0961	0.1414
4	0.0705	-0.1385	-0.0680	0.0903	-0.0807	0.0096	0.1734	-0.1240	0.0494	0.2375	-0.0855	0.1520
5	0.0752	-0.1251	-0.0499	0.0950	-0.0728	0.0222	0.1734	-0.1106	0.0628	0.2423	-0.0752	0.1671
6	0.0705	-0.1118	-0.0412	0.0903	-0.0649	0.0253	0.1782	-0.0972	0.0810	0.2374	-0.0650	0.1724
7	0.0705	-0.0984	-0.0278	0.0903	-0.0571	0.0332	0.1734	-0.0838	0.0895	0.2374	-0.0547	0.1827
8	0.0752	-0.0850	-0.0098	0.0950	-0.0492	0.0458	0.1733	-0.0705	0.1029	0.2422	-0.0445	0.1977
9	0.0705	-0.0720	-0.0015	0.0903	-0.0413	0.0489	0.1733	-0.0571	0.1163	0.2373	-0.0342	0.2031
10	0.0705	-0.0586	0.0119	0.0903	-0.0334	0.0568	0.1781	-0.0437	0.1344	0.2373	-0.0240	0.2133
11	0.0752	-0.0452	0.0300	0.0950	-0.0256	0.0694	0.1733	-0.0303	0.1430	0.2421	-0.0138	0.2283
12	0.0705	-0.0319	0.0387	0.0902	-0.0177	0.0725	0.1733	-0.0173	0.1559	0.2372	-0.0031	0.2340
13	0.0705	-0.0189	0.0516	0.0902	-0.0098	0.0804	0.1732	-0.0039	0.1693	0.2372	0.0071	0.2442
14	0.0752	-0.0055	0.0697	0.0950	-0.0020	0.0930	0.1780	0.0094	0.1875	0.2420	0.0173	0.2593
exit	0.0705	0.0000	0.0705	0.0902	0.0000	0.0902	0.1732	0.0000	0.1732	0.2371	0.0000	0.2371
TOTAL q _c	1.0814	-1.2856	-0.2042	1.3778	-0.7438	0.6340	2.6194	-1.0805	1.5389	3.5845	-0.6949	2.8896
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2999	-0.0722	0.2277	0.2993	-0.0355	0.2638	0.3411	-0.0083	0.3328	0.3900	-0.0008	0.3892
2	0.2949	-0.0674	0.2275	0.2992	-0.0355	0.2637	0.3410	-0.0075	0.3335	0.3850	-0.0004	0.3846
3	0.2998	-0.0631	0.2367	0.2991	-0.0355	0.2636	0.3409	-0.0067	0.3342	0.3898	0.0000	0.3898
4	0.2948	-0.0587	0.2360	0.2991	-0.0355	0.2636	0.3408	-0.0063	0.3345	0.3847	0.0004	0.3851
5	0.2996	-0.0544	0.2452	0.2990	-0.0355	0.2635	0.3407	-0.0055	0.3352	0.3895	0.0008	0.3903
6	0.2995	-0.0496	0.2499	0.2989	-0.0355	0.2634	0.3406	-0.0051	0.3355	0.3894	0.0008	0.3902
7	0.2946	-0.0453	0.2493	0.2988	-0.0351	0.2637	0.3405	-0.0043	0.3362	0.3843	0.0012	0.3855
8	0.2994	-0.0410	0.2584	0.2938	-0.0351	0.2588	0.3404	-0.0035	0.3368	0.3891	0.0016	0.3907
9	0.2944	-0.0366	0.2578	0.2987	-0.0351	0.2636	0.3403	-0.0032	0.3371	0.3841	0.0020	0.3860
10	0.2993	-0.0319	0.2674	0.2986	-0.0351	0.2636	0.3402	-0.0024	0.3378	0.3889	0.0024	0.3912
11	0.2992	-0.0276	0.2717	0.2986	-0.0351	0.2635	0.3401	-0.0016	0.3386	0.3888	0.0028	0.3915
12	0.2943	-0.0232	0.2710	0.2985	-0.0350	0.2634	0.3401	-0.0012	0.3389	0.3838	0.0031	0.3869
13	0.2991	-0.0189	0.2802	0.2984	-0.0346	0.2638	0.3400	-0.0004	0.3396	0.3886	0.0035	0.3921
14	0.2941	-0.0142	0.2800	0.2984	-0.0346	0.2637	0.3399	0.0000	0.3399	0.3835	0.0039	0.3875
exit	0.2990	0.0000	0.2990	0.2983	0.0000	0.2983	0.3398	0.0000	0.3398	0.3884	0.0000	0.3884
TOTAL q _c	4.4618	-0.6041	3.8578	4.4766	-0.4927	3.9839	5.1064	-0.0560	5.0503	5.8077	0.0213	5.8290

Table M18: Coil Set Energy Balance for R4-36 at 5.5LPM

Coilset	1 second			2 seconds			3 seconds			5 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0108	0.0000	0.0108	0.0144	-0.0806	-0.0662	0.0217	-0.0842	-0.0625	0.0327	-0.0972	-0.0644
2	0.0072	0.0000	0.0072	0.0144	-0.0751	-0.0607	0.0217	-0.0779	-0.0562	0.0364	-0.0897	-0.0533
3	0.0108	0.0000	0.0108	0.0180	-0.0692	-0.0512	0.0180	-0.0716	-0.0536	0.0327	-0.0826	-0.0499
4	0.0108	0.0000	0.0108	0.0144	-0.0633	-0.0489	0.0217	-0.0653	-0.0436	0.0364	-0.0755	-0.0392
5	0.0108	0.0000	0.0108	0.0144	-0.0578	-0.0434	0.0217	-0.0590	-0.0374	0.0327	-0.0681	-0.0353
6	0.0072	0.0000	0.0072	0.0144	-0.0519	-0.0375	0.0217	-0.0527	-0.0311	0.0364	-0.0610	-0.0246
7	0.0108	0.0000	0.0108	0.0144	-0.0460	-0.0316	0.0217	-0.0464	-0.0248	0.0327	-0.0539	-0.0212
8	0.0108	0.0000	0.0108	0.0180	-0.0405	-0.0225	0.0180	-0.0401	-0.0221	0.0364	-0.0464	-0.0100
9	0.0108	0.0000	0.0108	0.0144	-0.0346	-0.0202	0.0217	-0.0338	-0.0122	0.0327	-0.0393	-0.0066
10	0.0072	0.0000	0.0072	0.0144	-0.0287	-0.0143	0.0217	-0.0275	-0.0059	0.0364	-0.0323	0.0041
11	0.0108	0.0000	0.0108	0.0144	-0.0232	-0.0088	0.0217	-0.0212	0.0004	0.0327	-0.0248	0.0079
12	0.0108	0.0000	0.0108	0.0144	-0.0173	-0.0029	0.0217	-0.0149	0.0067	0.0364	-0.0177	0.0187
13	0.0108	0.0000	0.0108	0.0180	-0.0114	0.0066	0.0180	-0.0087	0.0094	0.0327	-0.0106	0.0221
14	0.0072	0.0000	0.0072	0.0144	-0.0059	0.0085	0.0217	-0.0024	0.0193	0.0364	-0.0031	0.0332
exit	0.0108	0.0000	0.0108	0.0144	0.0000	0.0144	0.0217	0.0000	0.0217	0.0327	0.0000	0.0327
TOTAL q _c	0.1477	0.0000	0.1477	0.2274	-0.6058	-0.3784	0.3140	-0.6058	-0.2918	0.5165	-0.7023	-0.1858
Coilset	8 seconds			10 seconds			15 seconds			20 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.0589	-0.1086	-0.0497	0.0812	-0.1756	-0.0944	0.1321	-0.1205	0.0116	0.1740	-0.0871	0.0869
2	0.0552	-0.1008	-0.0455	0.0848	-0.1622	-0.0774	0.1321	-0.1107	0.0214	0.1702	-0.0788	0.0914
3	0.0589	-0.0925	-0.0336	0.0811	-0.1488	-0.0677	0.1358	-0.1004	0.0354	0.1740	-0.0709	0.1030
4	0.0552	-0.0846	-0.0294	0.0848	-0.1354	-0.0506	0.1321	-0.0906	0.0415	0.1701	-0.0626	0.1075
5	0.0589	-0.0763	-0.0175	0.0811	-0.1220	-0.0409	0.1320	-0.0803	0.0517	0.1739	-0.0543	0.1196
6	0.0589	-0.0685	-0.0096	0.0811	-0.1086	-0.0275	0.1320	-0.0701	0.0619	0.1739	-0.0461	0.1278
7	0.0552	-0.0606	-0.0054	0.0848	-0.0952	-0.0104	0.1320	-0.0602	0.0718	0.1701	-0.0378	0.1323
8	0.0589	-0.0523	0.0065	0.0811	-0.0819	-0.0007	0.1358	-0.0500	0.0858	0.1738	-0.0299	0.1439
9	0.0552	-0.0445	0.0107	0.0848	-0.0685	0.0163	0.1320	-0.0401	0.0918	0.1700	-0.0216	0.1484
10	0.0589	-0.0362	0.0227	0.0811	-0.0551	0.0260	0.1320	-0.0299	0.1021	0.1738	-0.0134	0.1604
11	0.0589	-0.0283	0.0305	0.0811	-0.0417	0.0394	0.1319	-0.0197	0.1123	0.1737	-0.0051	0.1686
12	0.0552	-0.0201	0.0351	0.0848	-0.0283	0.0564	0.1319	-0.0098	0.1221	0.1699	0.0031	0.1731
13	0.0589	-0.0122	0.0467	0.0811	-0.0149	0.0661	0.1357	0.0004	0.1361	0.1737	0.0110	0.1847
14	0.0552	-0.0039	0.0512	0.0848	-0.0016	0.0832	0.1319	0.0102	0.1421	0.1699	0.0193	0.1892
exit	0.0589	0.0000	0.0589	0.0811	0.0000	0.0811	0.1319	0.0000	0.1319	0.1736	0.0000	0.1736
TOTAL q _c	0.8610	-0.7894	0.0716	1.2388	-1.2398	-0.0010	1.9912	-0.7718	1.2194	2.5846	-0.4743	2.1103
Coilset	30 seconds			50 seconds			100 seconds			200 seconds		
	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)	Flow (kW)	Storage (kW)	Coil set q _c (kW)
1	0.2356	-0.0797	0.1560	0.2550	-0.0411	0.2140	0.2455	-0.0107	0.2348	0.2568	-0.0020	0.2548
2	0.2394	-0.0737	0.1657	0.2549	-0.0407	0.2143	0.2415	-0.0107	0.2309	0.2606	-0.0016	0.2590
3	0.2355	-0.0674	0.1681	0.2549	-0.0402	0.2146	0.2454	-0.0111	0.2343	0.2566	-0.0016	0.2550
4	0.2354	-0.0611	0.1744	0.2508	-0.0398	0.2109	0.2453	-0.0111	0.2342	0.2604	-0.0012	0.2592
5	0.2354	-0.0552	0.1802	0.2547	-0.0398	0.2149	0.2413	-0.0110	0.2303	0.2565	-0.0012	0.2553
6	0.2392	-0.0488	0.1904	0.2547	-0.0394	0.2152	0.2452	-0.0110	0.2341	0.2603	-0.0012	0.2591
7	0.2353	-0.0425	0.1928	0.2546	-0.0390	0.2156	0.2451	-0.0110	0.2340	0.2563	-0.0008	0.2555
8	0.2352	-0.0366	0.1986	0.2545	-0.0386	0.2159	0.2411	-0.0110	0.2301	0.2601	-0.0008	0.2593
9	0.2352	-0.0303	0.2049	0.2545	-0.0382	0.2163	0.2449	-0.0110	0.2339	0.2562	-0.0008	0.2554
10	0.2390	-0.0240	0.2150	0.2544	-0.0382	0.2162	0.2449	-0.0110	0.2339	0.2600	-0.0004	0.2596
11	0.2351	-0.0181	0.2170	0.2544	-0.0378	0.2166	0.2409	-0.0110	0.2299	0.2560	-0.0004	0.2556
12	0.2350	-0.0118	0.2232	0.2503	-0.0374	0.2129	0.2448	-0.0110	0.2338	0.2599	0.0000	0.2599
13	0.2350	-0.0055	0.2295	0.2543	-0.0370	0.2173	0.2447	-0.0110	0.2337	0.2559	0.0000	0.2559
14	0.2388	0.0004	0.2392	0.2542	-0.0366	0.2176	0.2408	-0.0110	0.2298	0.2597	0.0000	0.2597
exit	0.2349	0.0000	0.2349	0.2541	0.0000	0.2541	0.2446	0.0000	0.2446	0.2558	0.0000	0.2558
TOTAL q _c	3.5442	-0.5544	2.9898	3.8102	-0.5439	3.2663	3.6560	-0.1538	3.5023	3.8711	-0.0118	3.8593

Appendix N: Summarized Energy Balance Data Tables

Table N1: Energy Balance Data at 14 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.1213	0.0000	0.1213	0.8198	0.0000	0.8198	0.0383	0.0000	0.0383
2	0.1408	-0.1028	0.0380	1.0453	-0.3070	0.7383	0.0165	0.0000	0.0165
3	0.1727	-0.0514	0.1213	1.3952	-0.9211	0.4741	0.0187	-0.1101	-0.0914
5	1.5796	-1.2850	0.2947	2.9041	-2.3734	0.5308	1.1131	-1.5561	-0.4429
8	4.6508	-1.8860	2.7649	5.6260	-2.7941	2.8320	3.5848	-2.3147	1.2701
10	5.6625	-1.3633	4.2991	6.8022	-1.4953	5.3069	5.1358	-2.0261	3.1097
15	7.4541	-1.1807	6.2734	9.5188	-1.0238	8.4950	7.9319	-2.0304	5.9015
20	8.8095	-0.6867	8.1228	11.6851	-0.6882	10.9969	8.6582	-1.2141	7.4441
30	9.1649	-0.4242	8.7407	12.3056	-0.4616	11.8441	8.9817	-0.6625	8.3192
50	9.1789	-0.1261	9.0528	12.2032	-0.1581	12.0451	8.7957	-0.2733	8.5224
100	9.3273	-0.0204	9.3070	12.4023	-0.0236	12.3787	8.7717	-0.0292	8.7425
200	9.3568	-0.0034	9.3534	12.5513	-0.0056	12.5457	8.8469	-0.0032	8.8437

Table N2: Energy Balance Data at 12 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.1208	0.0000	0.1208	0.3844	0.0000	0.3844	0.1716	0.0000	0.1716
2	0.1459	-0.0343	0.1117	0.5206	-0.5023	0.0183	0.7959	-2.0377	-1.2418
3	0.1721	-0.0514	0.1208	1.4851	-3.3219	-1.8368	1.3223	-1.7075	-0.3852
5	1.2741	-1.1650	0.1091	2.6197	-1.8848	0.7349	3.0291	-2.8104	0.2187
8	2.4460	-0.7827	1.6633	4.7453	-2.2165	2.5288	5.0710	-1.9849	3.0861
10	3.9993	-1.7059	2.2934	6.2437	-1.7889	4.4548	5.9369	-1.1581	4.7788
15	6.1837	-1.2319	4.9519	8.2850	-0.6211	7.6639	7.1637	-1.0591	6.1045
20	7.2287	-0.4840	6.7447	9.8158	-0.4366	9.3792	7.9415	-1.1036	6.8379
30	7.9842	-0.3743	7.6099	10.8742	-0.4112	10.4631	8.0268	-0.5547	7.4721
50	8.1498	-0.1693	7.9806	10.9070	-0.1899	10.7171	7.9211	-0.2500	7.6711
100	8.2761	-0.0282	8.2479	11.1642	-0.0336	11.1307	8.0008	-0.0383	7.9626
200	8.3607	-0.0032	8.3575	11.3382	-0.0037	11.3345	8.0848	-0.0055	8.0793

Table N3: Energy Balance Data at 10 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.3010	0.0000	0.3010	0.7054	0.0000	0.7054	0.0000	0.0000	0.0000
2	0.3496	-0.1199	0.2297	0.9233	-0.8652	0.0581	0.0134	-0.0551	-0.0417
3	0.4053	-0.1370	0.2683	1.2416	-1.3398	-0.0982	0.0269	-0.0551	-0.0282
5	0.9609	-0.7281	0.2328	2.0324	-1.6194	0.4131	0.7534	-1.3632	-0.6098
8	2.5756	-1.3883	1.1873	3.2370	-1.6759	1.5611	2.3866	-2.0389	0.3477
10	3.6005	-1.4402	2.1603	4.3582	-2.0677	2.2905	3.1288	-1.3229	1.8060
15	5.0702	-0.9092	4.1610	6.4876	-0.8893	5.5983	5.0292	-1.2740	3.7553
20	6.1502	-0.5458	5.6044	7.7283	-0.3751	7.3532	6.2353	-0.8938	5.3415
30	7.0774	-0.3176	6.7598	9.3026	-0.3583	8.9443	7.0695	-0.5408	6.5287
50	7.2815	-0.1793	7.1022	9.6802	-0.2224	9.4578	7.1276	-0.3245	6.8032
100	7.4515	-0.0368	7.4147	9.9168	-0.0515	9.8653	7.2134	-0.0635	7.1499
200	7.5512	-0.0047	7.5465	10.0815	-0.0051	10.0763	7.3046	-0.0063	7.2982

Table N4: Energy Balance Data at 9 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.6263	0.0000	0.6263	0.5758	0.0000	0.5758	0.1547	0.0000	0.1547
2	0.9006	-0.7538	0.1468	0.8842	-1.3399	-0.4557	0.2918	-0.5507	-0.2588
3	1.0584	-0.4283	0.6301	1.2002	-1.3680	-0.1678	0.8208	-2.2031	-1.3823
5	1.8760	-1.1482	0.7277	1.9007	-1.4940	0.4067	1.3233	-1.0604	0.2628
8	2.8178	-0.8858	1.9320	3.1839	-1.7410	1.4429	2.5007	-1.6989	0.8018
10	3.5939	-1.2175	2.3764	4.1001	-1.4952	2.6050	3.1026	-1.2540	1.8486
15	4.7620	-0.7240	4.0380	5.5567	-0.5426	5.0140	4.8425	-1.3292	3.5133
20	5.7091	-0.3811	5.3280	7.0026	-0.2578	6.7447	5.4856	-0.8109	4.6747
30	6.5790	-0.2816	6.2974	8.4621	-0.2436	8.2185	5.9669	-0.7836	5.1833
50	6.8744	-0.1572	6.7172	8.9279	-0.2126	8.7153	6.7516	-0.1298	6.6218
100	7.0078	-0.0366	6.9713	9.1918	-0.0543	9.1375	6.9012	-0.0603	6.8409
200	7.0862	-0.0044	7.0818	9.2455	-0.0068	9.2388	7.0060	-0.0055	7.0004

Table N5: Energy Balance Data at 7 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.4982	0.0000	0.4982	0.2168	0.0000	0.2168	0.0045	0.0000	0.0045
2	0.6318	-0.5310	0.1007	0.2561	-0.2791	-0.0230	0.0091	0.0275	0.0366
3	0.8038	-0.6510	0.1529	0.4770	-1.2003	-0.7232	0.0138	-0.0275	-0.0137
5	1.3365	-1.0281	0.3083	0.6346	-0.4466	0.1880	0.3607	-0.9225	-0.5618
8	1.8938	-0.6915	1.2023	1.4482	-1.7686	-0.3204	1.0814	-1.2856	-0.2042
10	2.2366	-0.6343	1.6023	1.8379	-1.0613	0.7765	1.3778	-0.7438	0.6340
15	3.2451	-0.6140	2.6311	3.1988	-1.1403	2.0586	2.6194	-1.0805	1.5389
20	4.1075	-0.3912	3.7162	4.2239	-0.3022	3.9217	3.5845	-0.6949	2.8896
30	5.1858	-0.2506	4.9352	6.2957	-0.0958	6.1999	4.4618	-0.6041	3.8578
50	5.8155	-0.1597	5.6558	7.3765	-0.1344	7.2421	4.4766	-0.4927	3.9839
100	6.0132	-0.0530	5.9602	7.7600	-0.0667	7.6934	5.1064	-0.0560	5.0503
200	6.1346	-0.0066	6.1279	7.9182	-0.0079	7.9102	5.8077	0.0213	5.8290

Table N6: Energy Balance Data at 5.5 LPM

Time (s)	R3-36			R3-60			R4-36		
	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)	Flow (kW)	Storage (kW)	Overall q_c (kW)
1	0.2637	0.0000	0.2637	0.1452	0.0000	0.1452	0.1477	0.0000	0.1477
2	0.3344	-0.3426	-0.0082	0.2029	-0.4467	-0.2438	0.2274	-0.6058	-0.3784
3	0.5107	-0.8223	-0.3116	0.3493	-1.0611	-0.7118	0.3140	-0.6058	-0.2918
5	0.6975	-0.4540	0.2435	0.5219	-0.6144	-0.0925	0.5165	-0.7023	-0.1858
8	1.0267	-0.4970	0.5297	0.8621	-0.8007	0.0614	0.8610	-0.7894	0.0716
10	1.3891	-0.7285	0.6607	1.1179	-0.8381	0.2798	1.2388	-1.2398	-0.0010
15	2.0551	-0.4698	1.5853	1.8285	-0.5925	1.2360	1.9912	-0.7718	1.2194
20	2.6618	-0.3773	2.2845	2.7508	-0.1682	2.5827	2.5846	-0.4743	2.1103
30	3.8344	-0.2352	3.5993	4.0438	0.0944	4.1383	3.5442	-0.5544	2.9898
50	4.8099	-0.1415	4.6683	5.5988	0.0219	5.6208	3.8102	-0.5439	3.2663
100	5.1283	-0.0684	5.0599	6.3799	-0.0611	6.3188	3.6560	-0.1538	3.5023
200	5.3055	-0.0113	5.2942	6.5143	-0.0075	6.5069	3.8711	-0.0118	3.8593

Appendix O: Energy Balance Plots

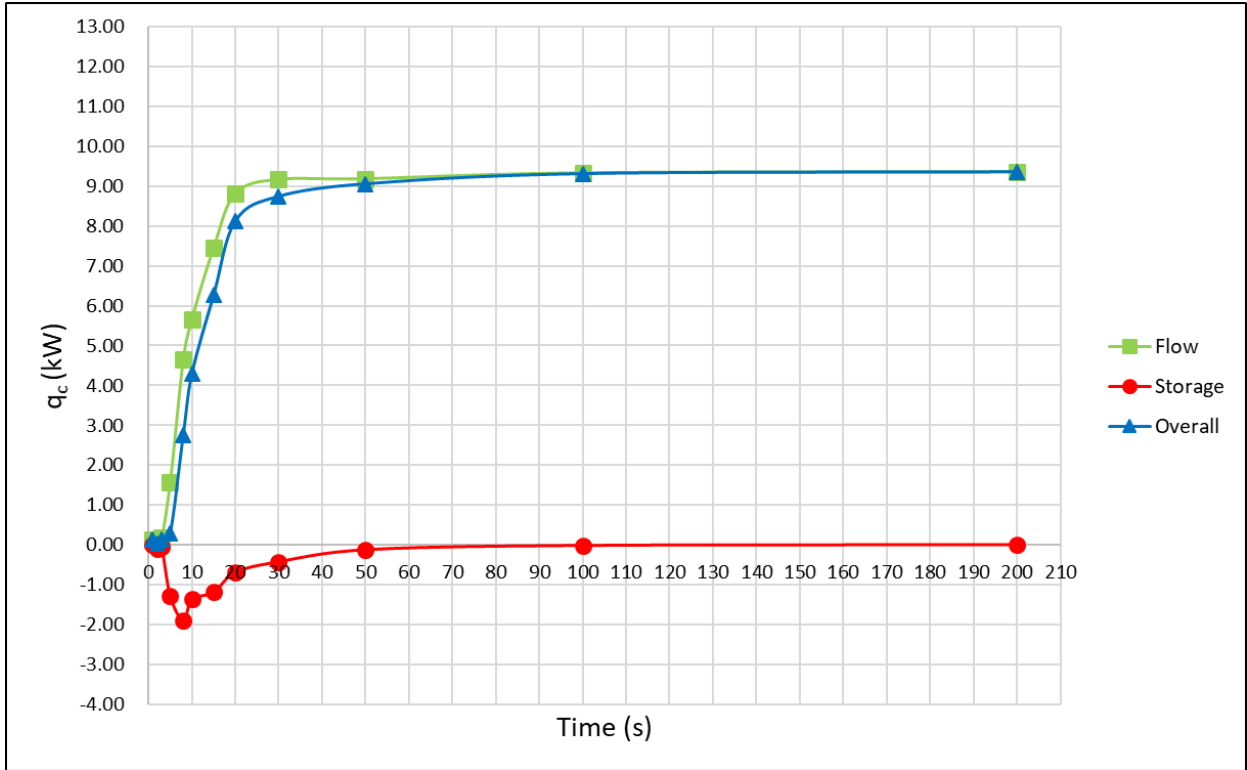


Figure O1: Mains-side energy balance plot for R3-36 at 14LPM

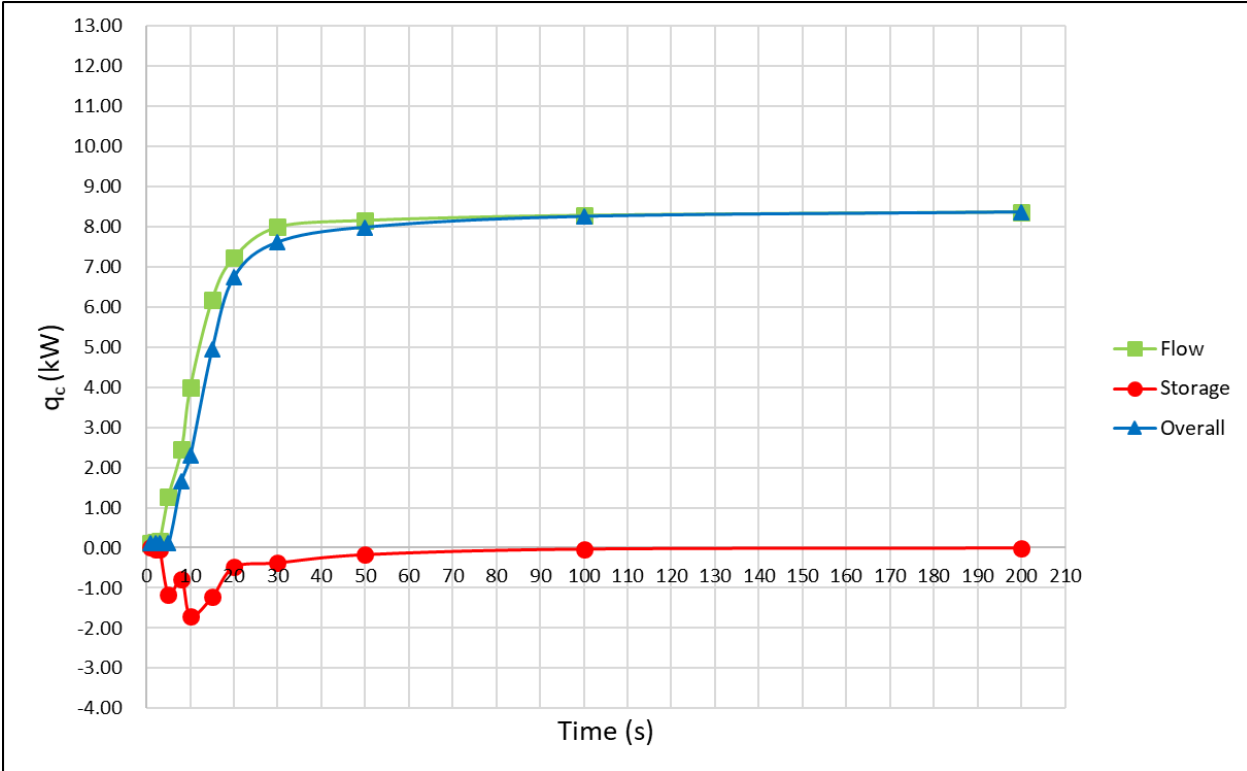


Figure O2: Mains-side energy balance plot for R3-36 at 12LPM

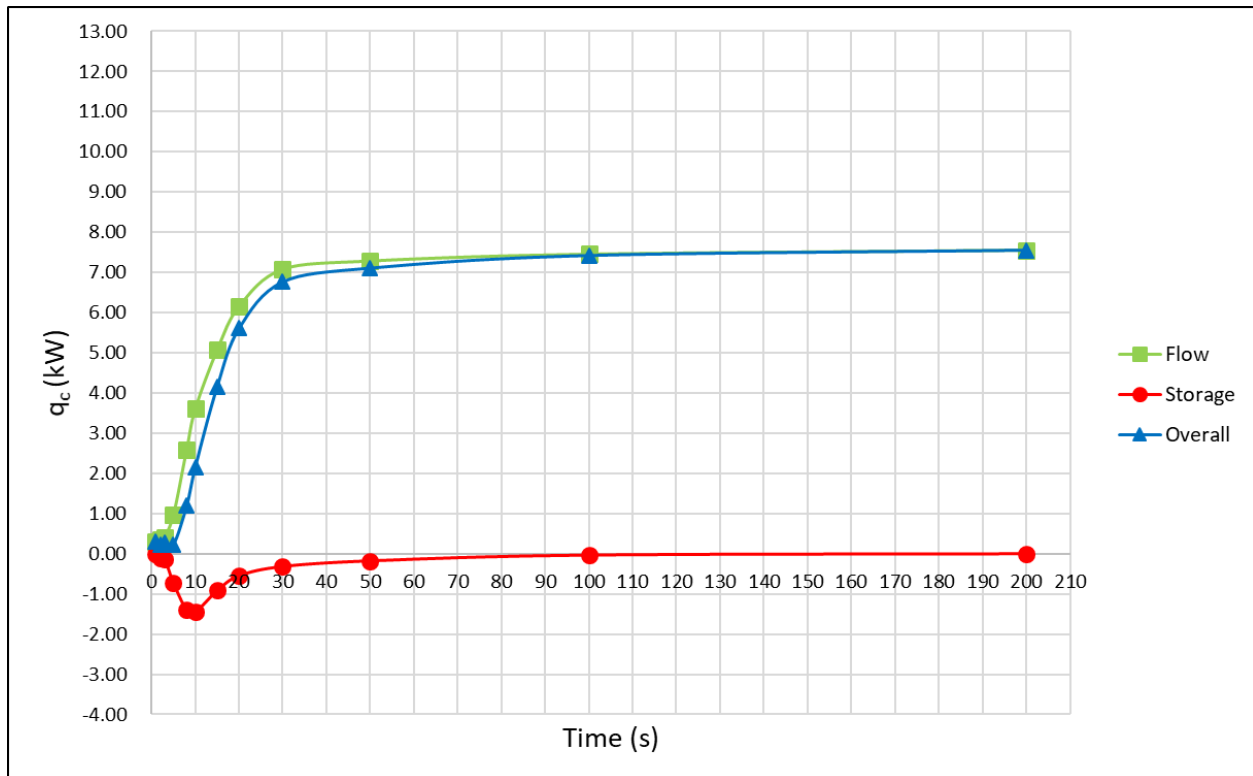


Figure O3: Mains-side energy balance plot for R3-36 at 10LPM

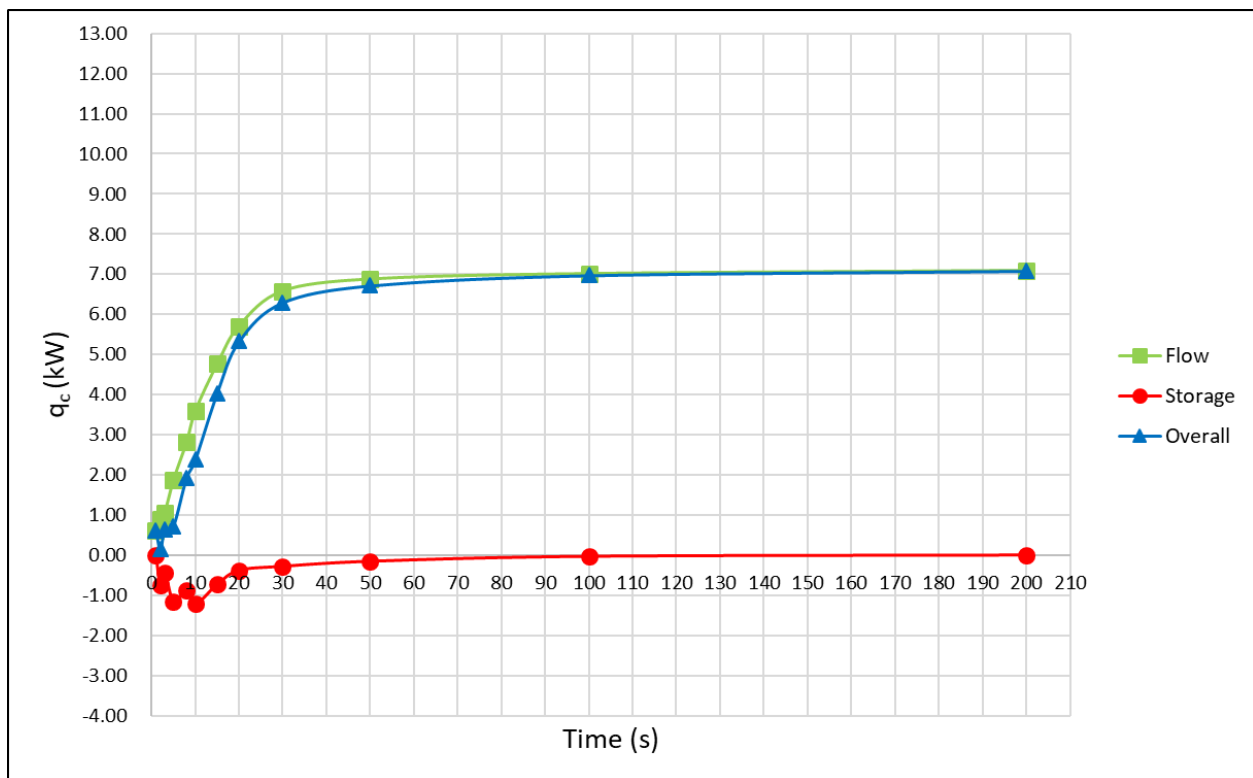


Figure O4: Mains-side energy balance plot for R3-36 at 9LPM

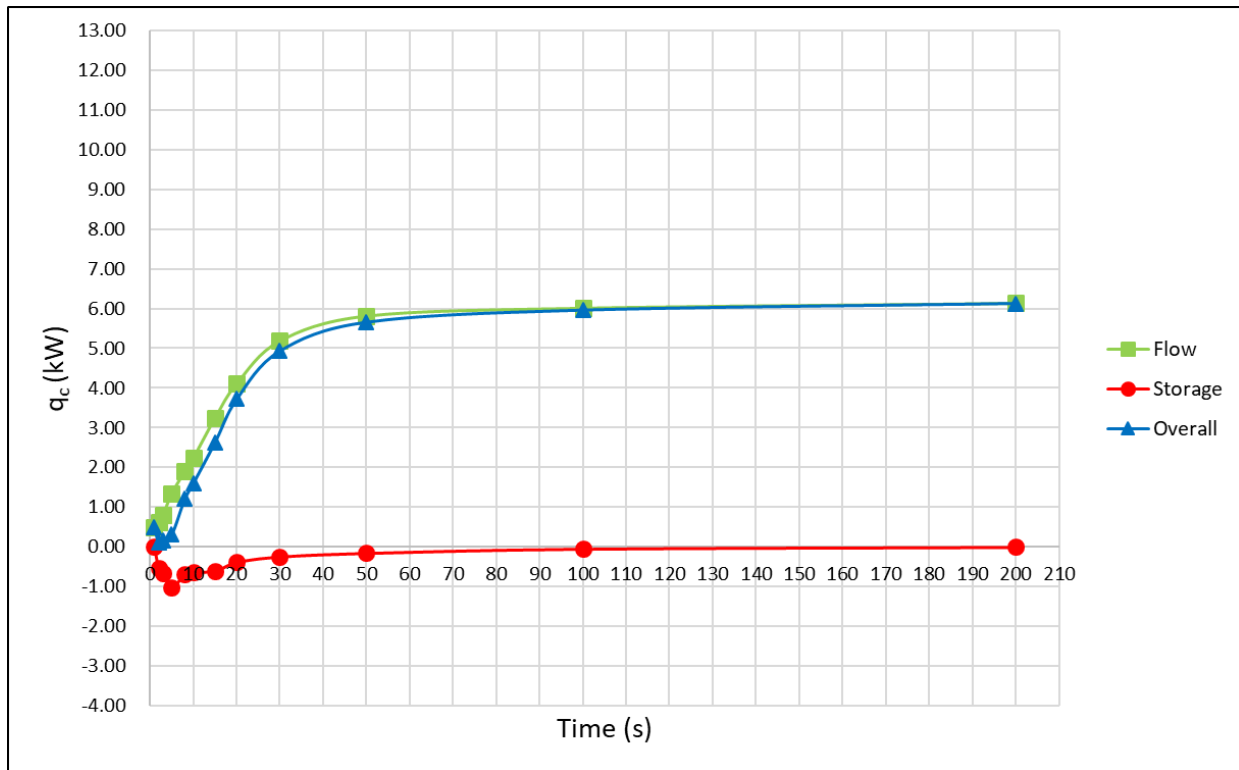


Figure O5: Mains-side energy balance plot for R3-36 at 7LPM

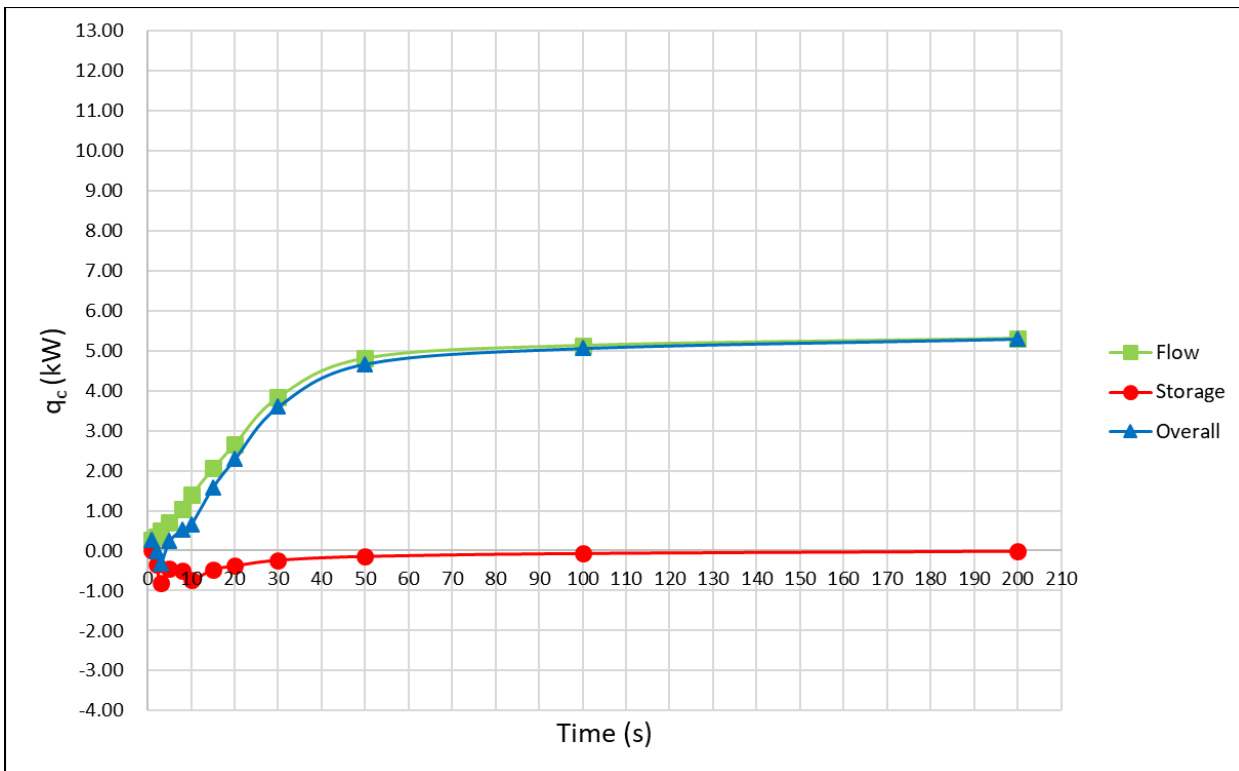


Figure O6: Mains-side energy balance plot for R3-36 at 5.5LPM

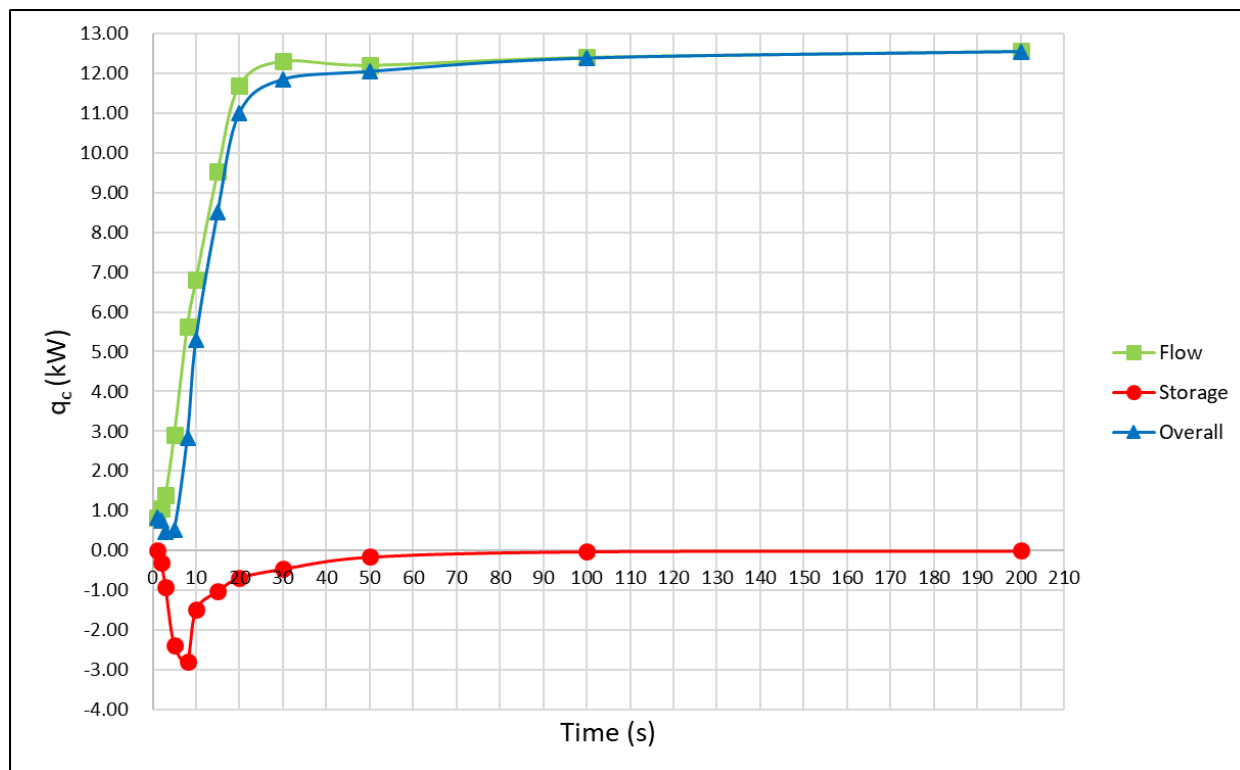


Figure O7: Mains-side energy balance plot for R3-60 at 14LPM

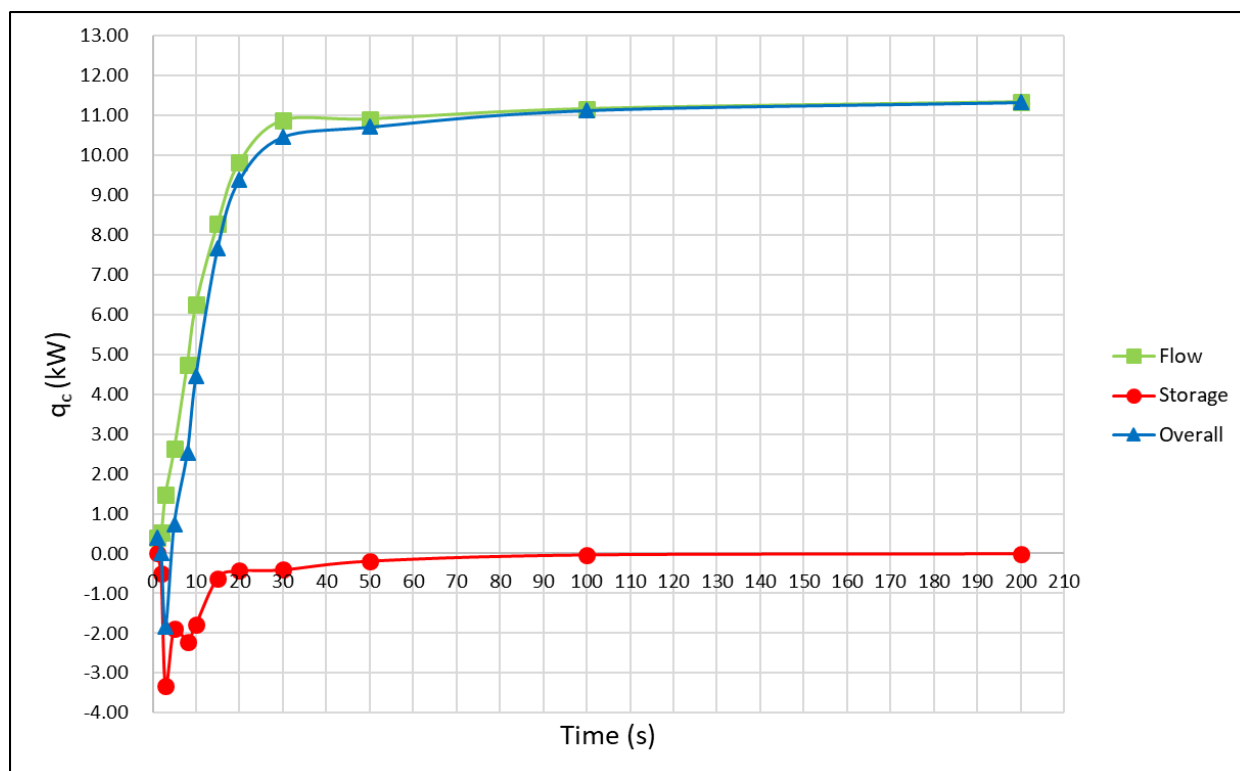


Figure O8: Mains-side energy balance plot for R3-60 at 12LPM

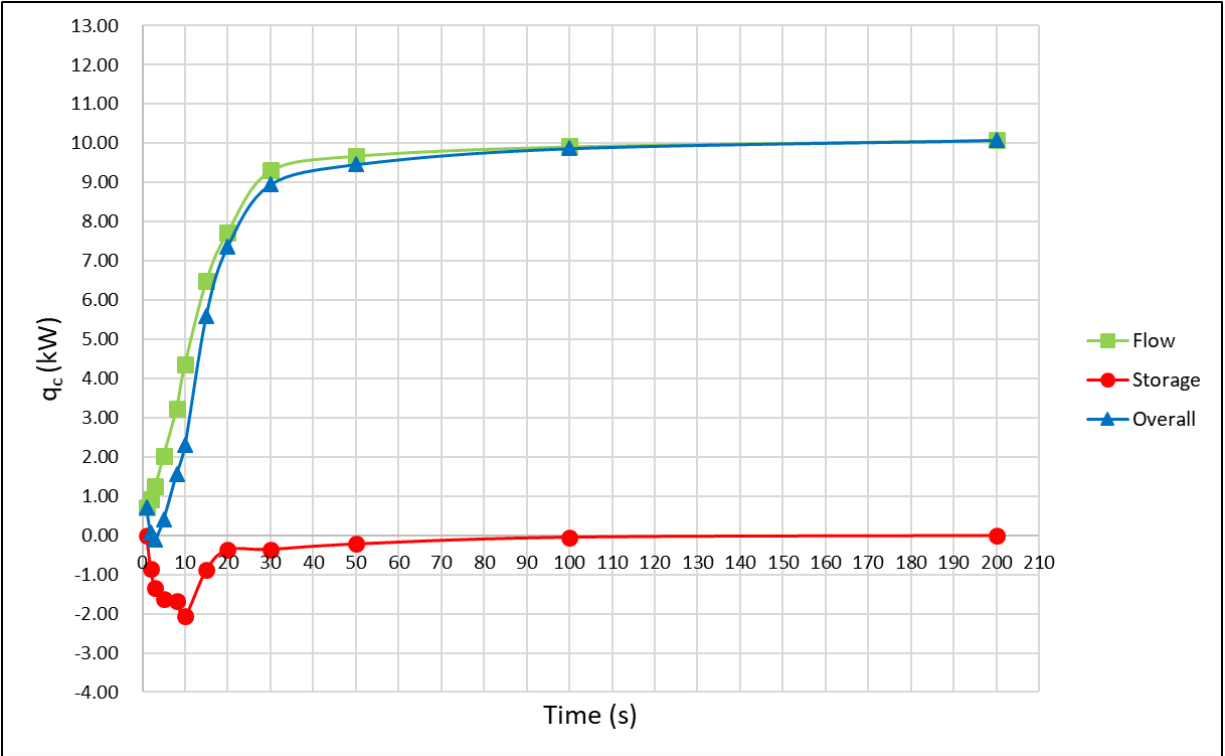


Figure O9: Mains-side energy balance plot for R3-60 at 10LPM

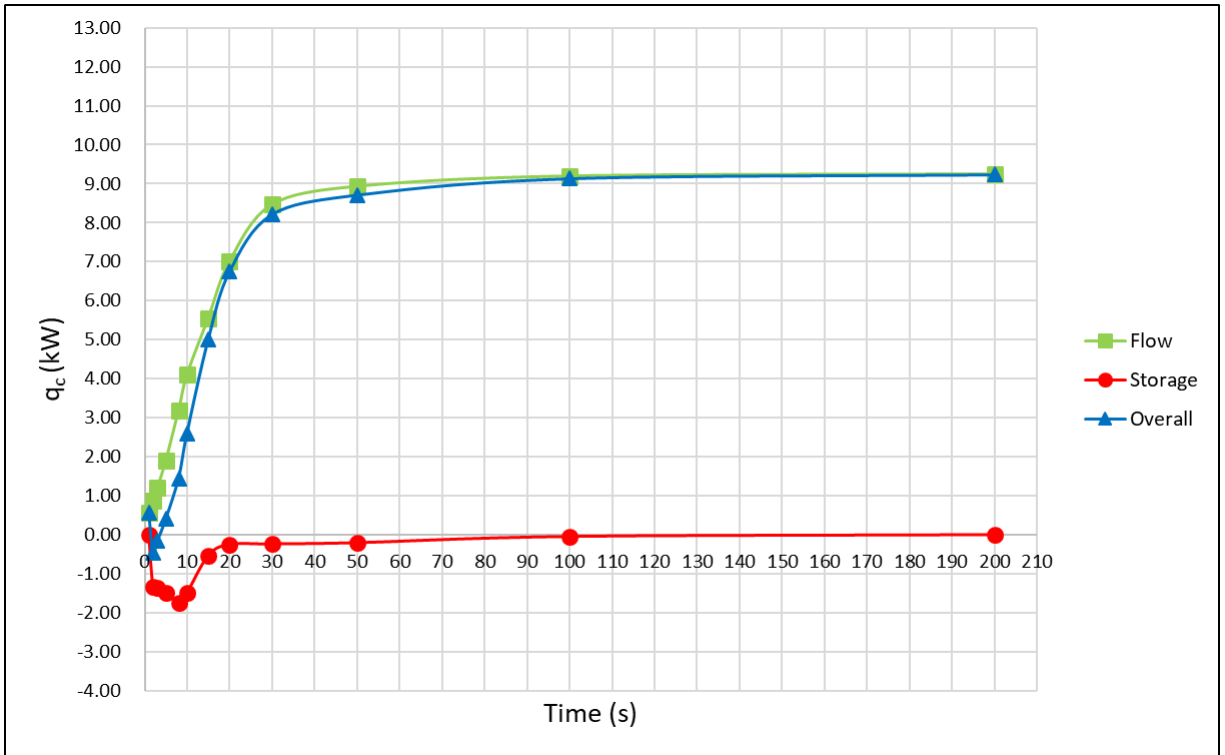


Figure O10: Mains-side energy balance plot for R3-60 at 9LPM

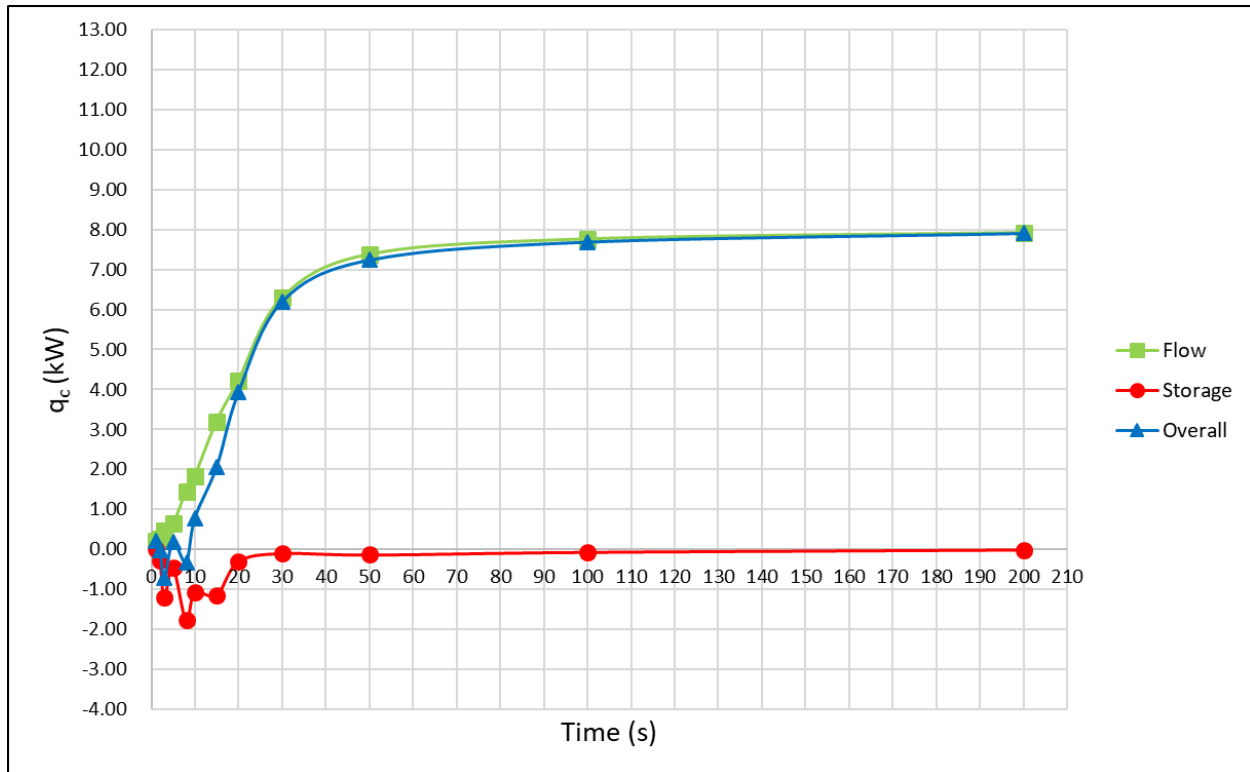


Figure O11: Mains-side energy balance plot for R3-60 at 7LPM

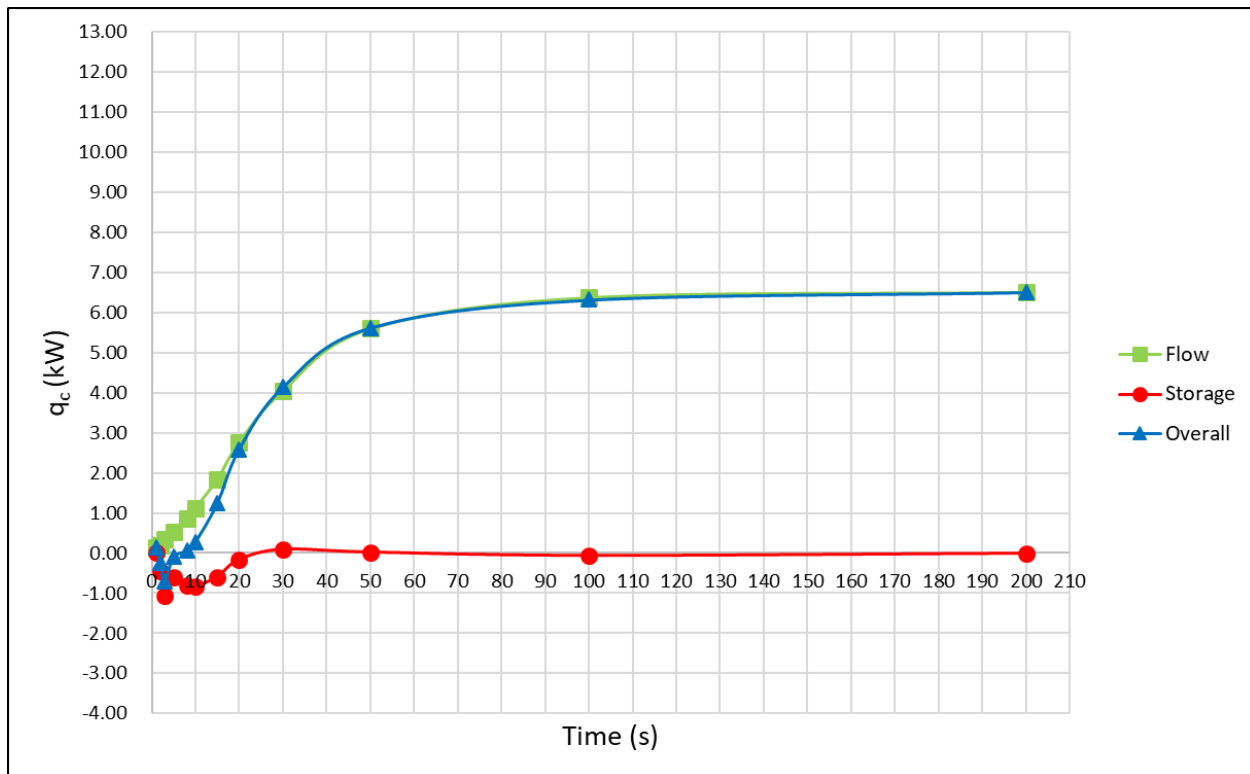


Figure O12: Mains-side energy balance plot for R3-60 at 5.5LPM

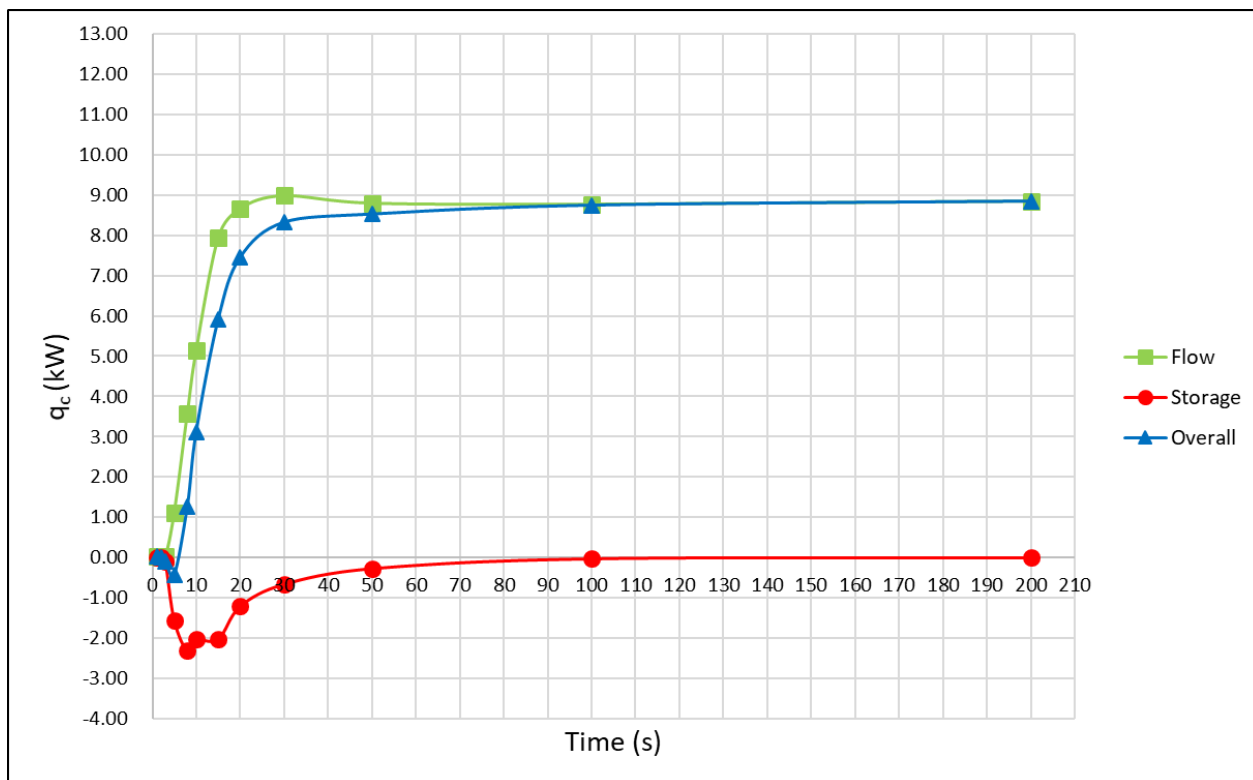


Figure O13: Mains-side energy balance plot for R4-36 at 14LPM

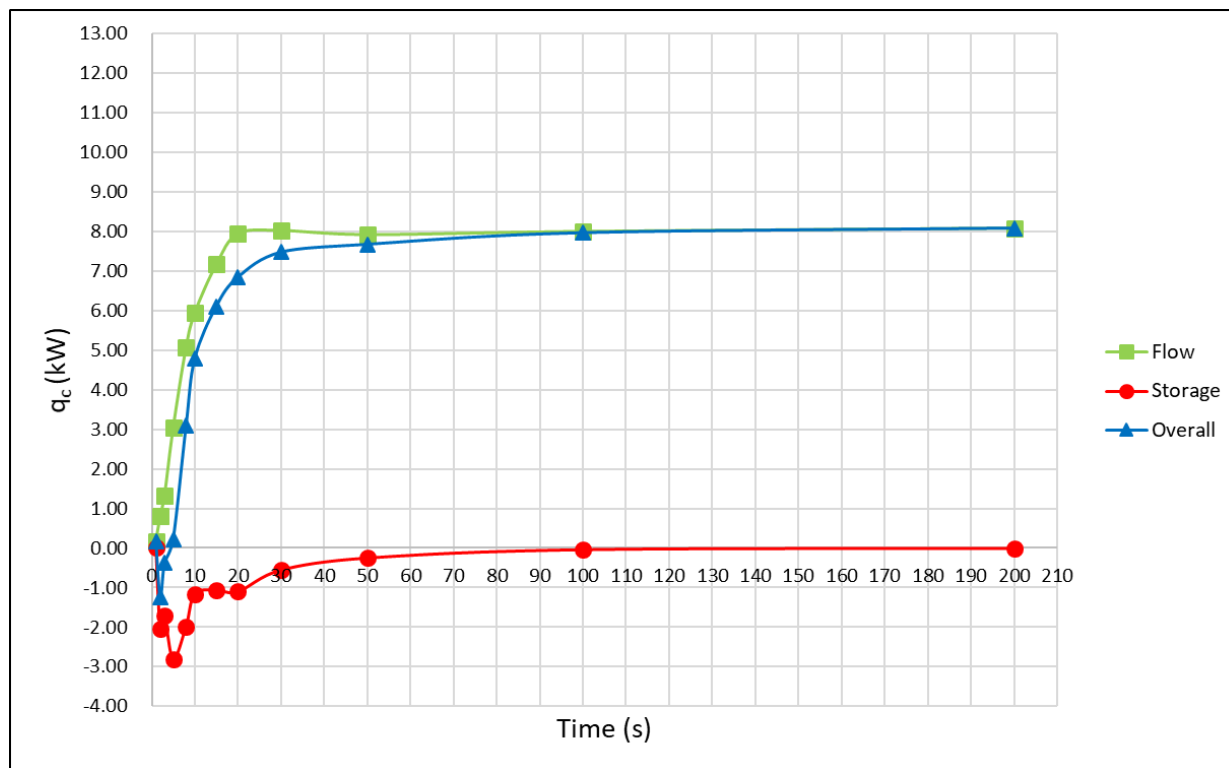


Figure O14: Mains-side energy balance plot for R4-36 at 12LPM

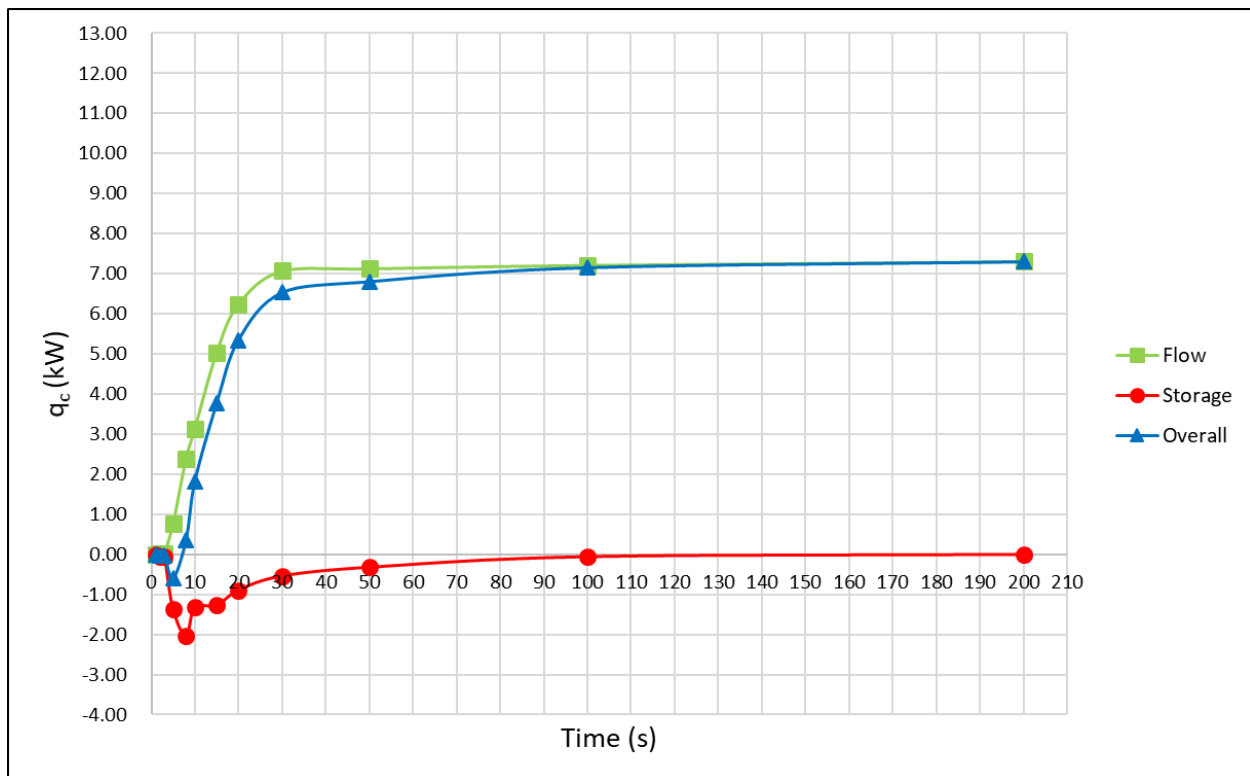


Figure O15: Mains-side energy balance plot for R4-36 at 10LPM

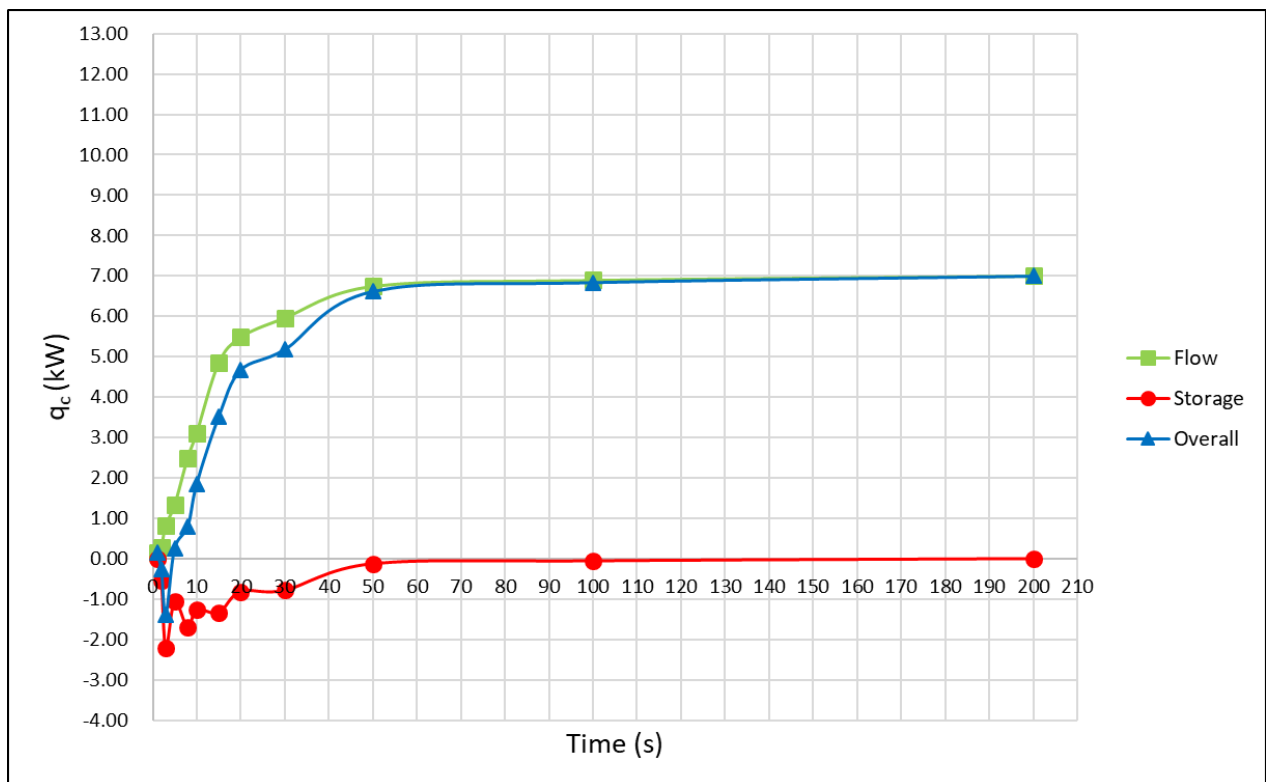


Figure O16: Mains-side energy balance plot for R4-36 at 9LPM

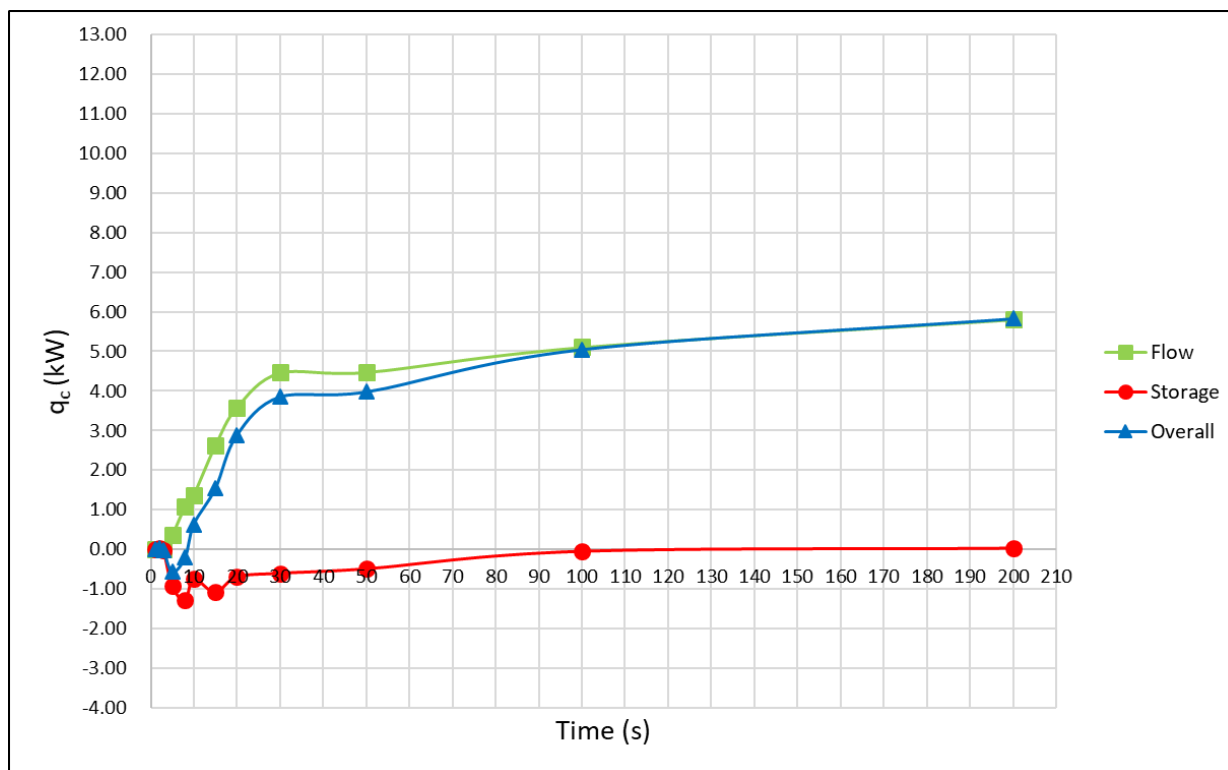


Figure O17: Mains-side energy balance plot for R4-36 at 7LPM

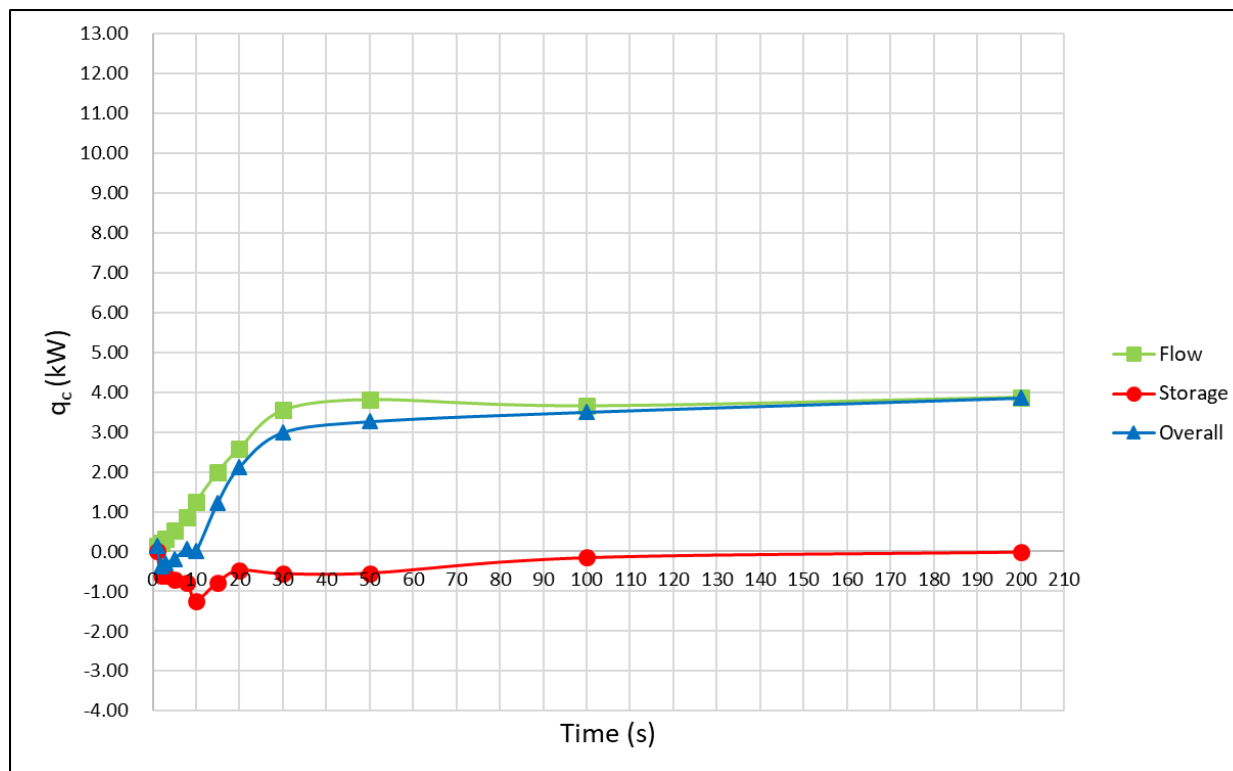


Figure O18: Mains-side energy balance plot for R4-36 at 5.5LPM

Appendix P: First Order Time Response Plots for q_c

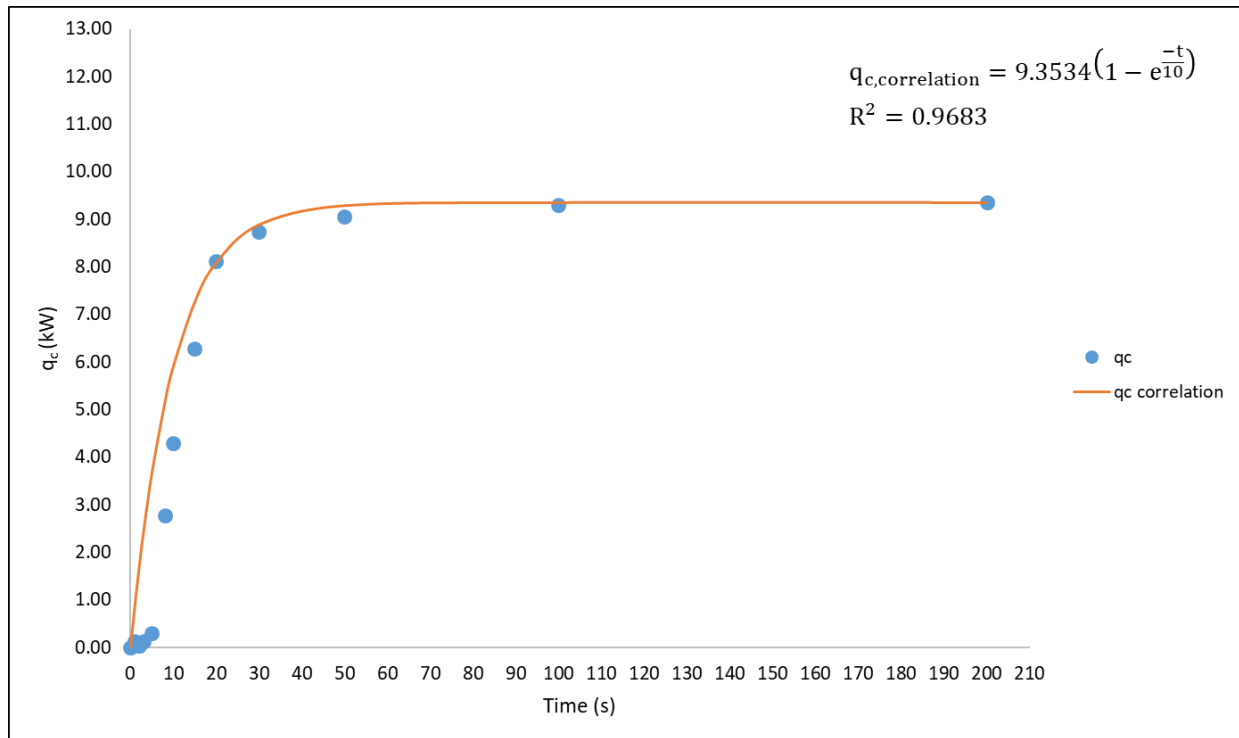


Figure P1: First order time response for R3-36 at 14LPM

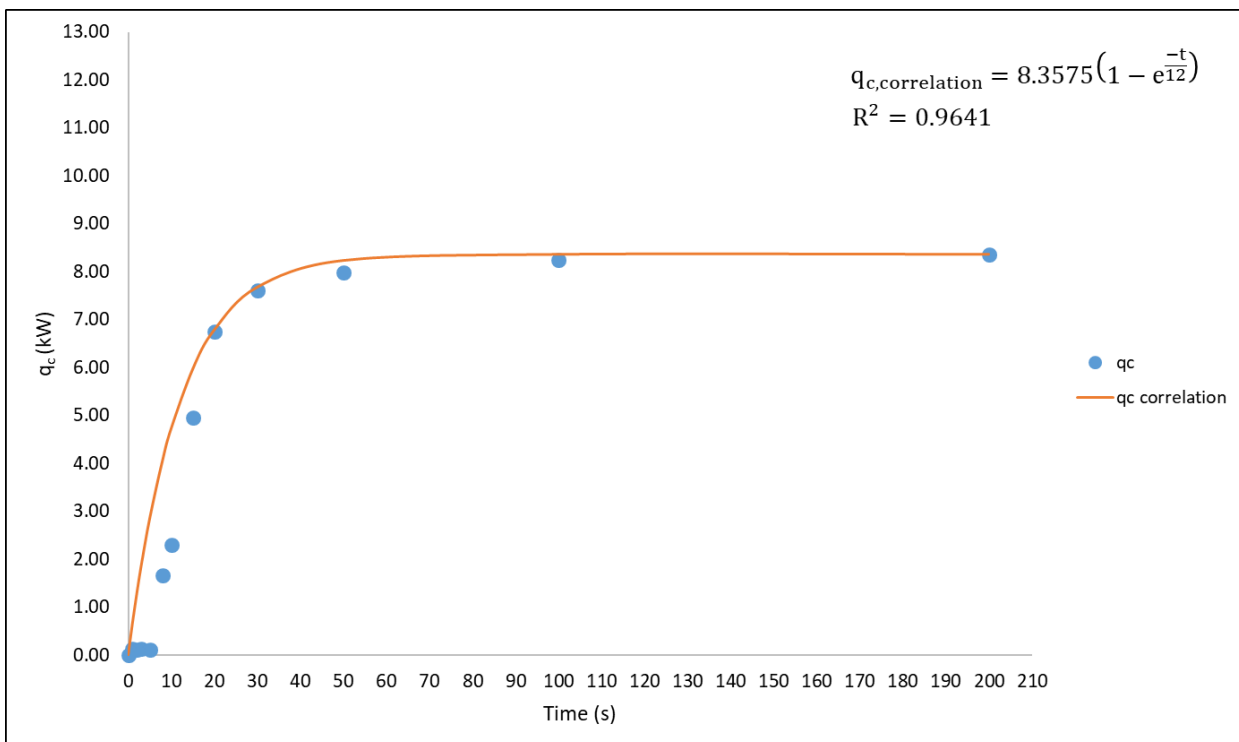


Figure P2: First order time response for R3-36 at 12LPM

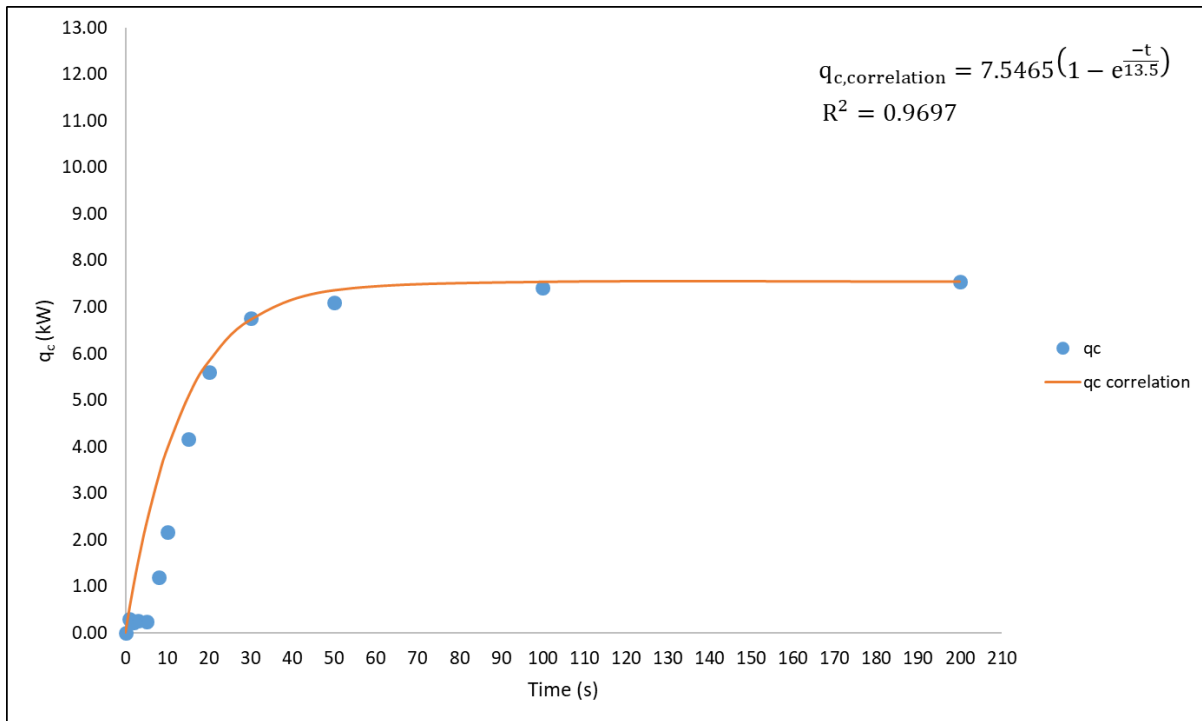


Figure P3: First order time response for R3-36 at 10LPM

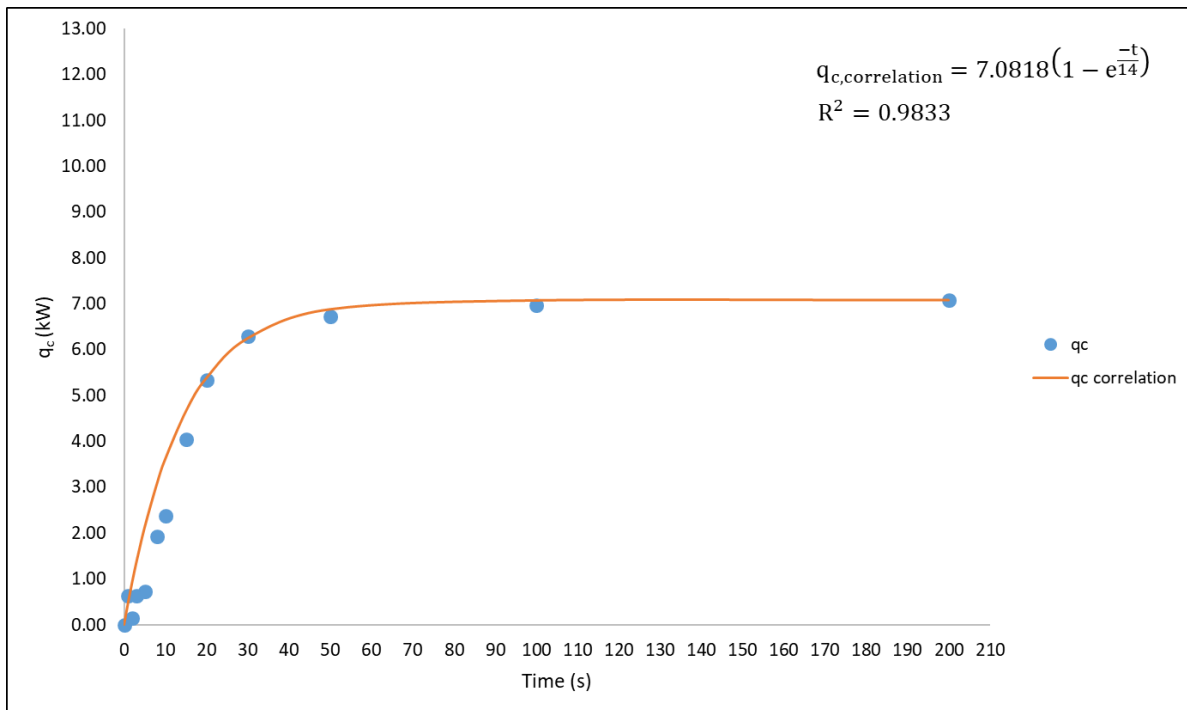


Figure P4: First order time response for R3-36 at 9LPM

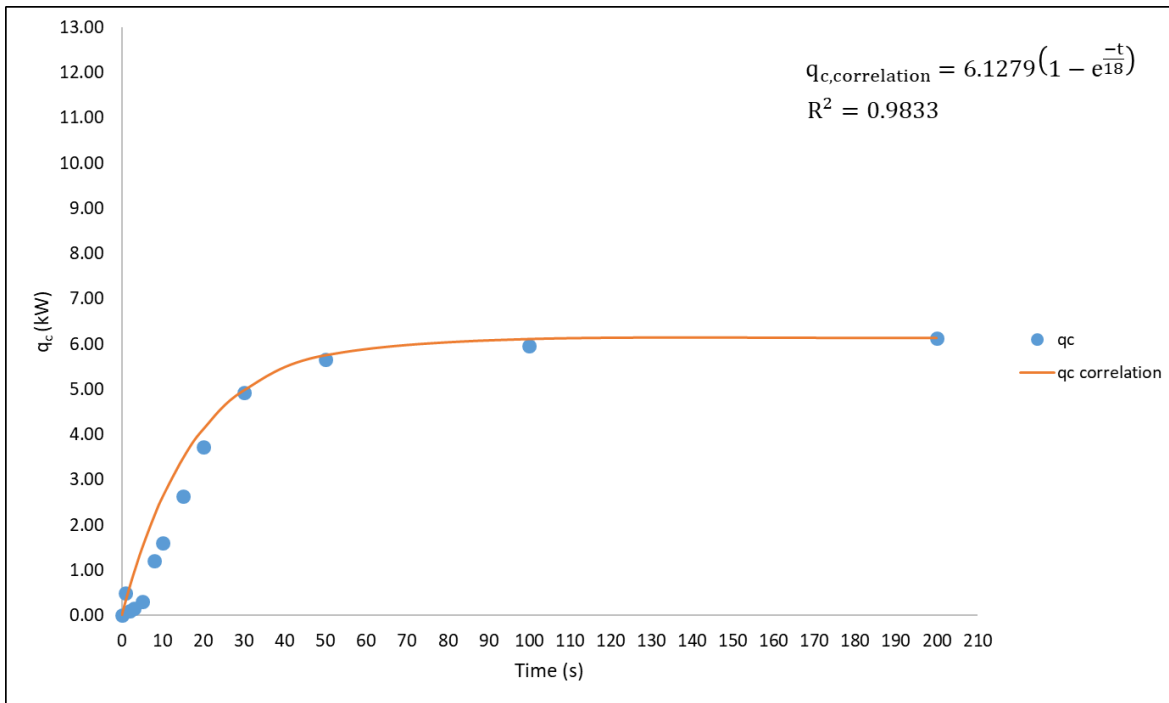


Figure P5: First order time response for R3-36 at 7LPM

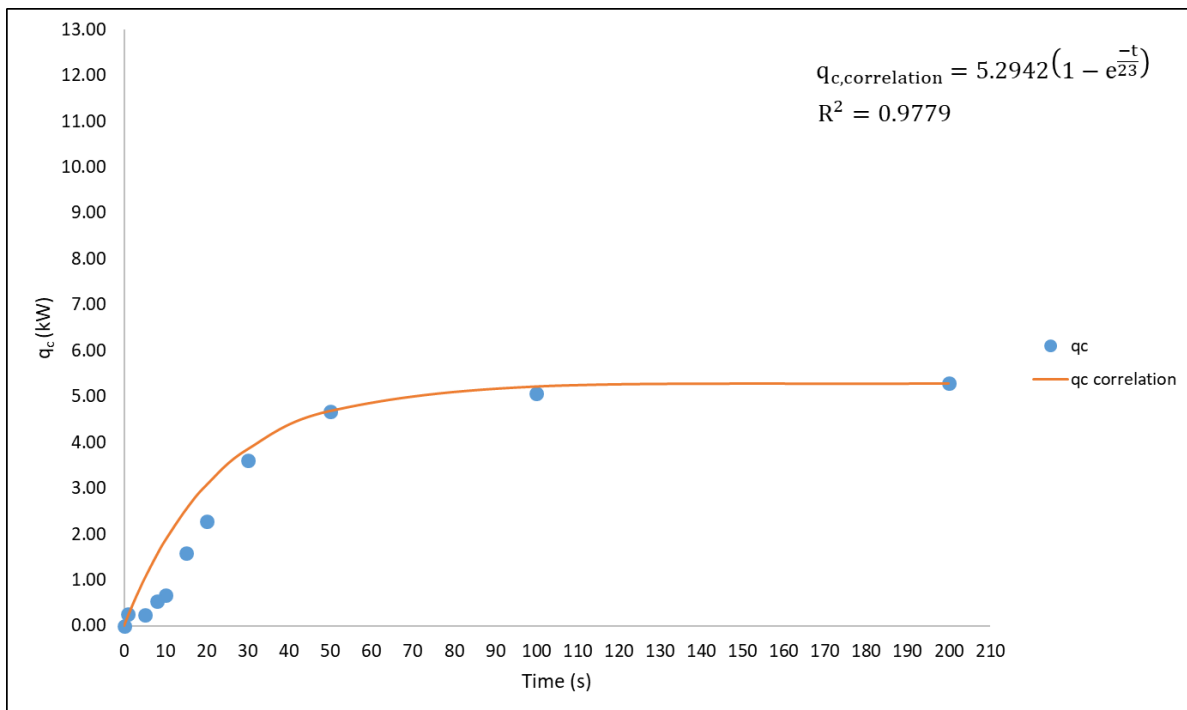


Figure P6: First order time response for R3-36 at 5.5LPM

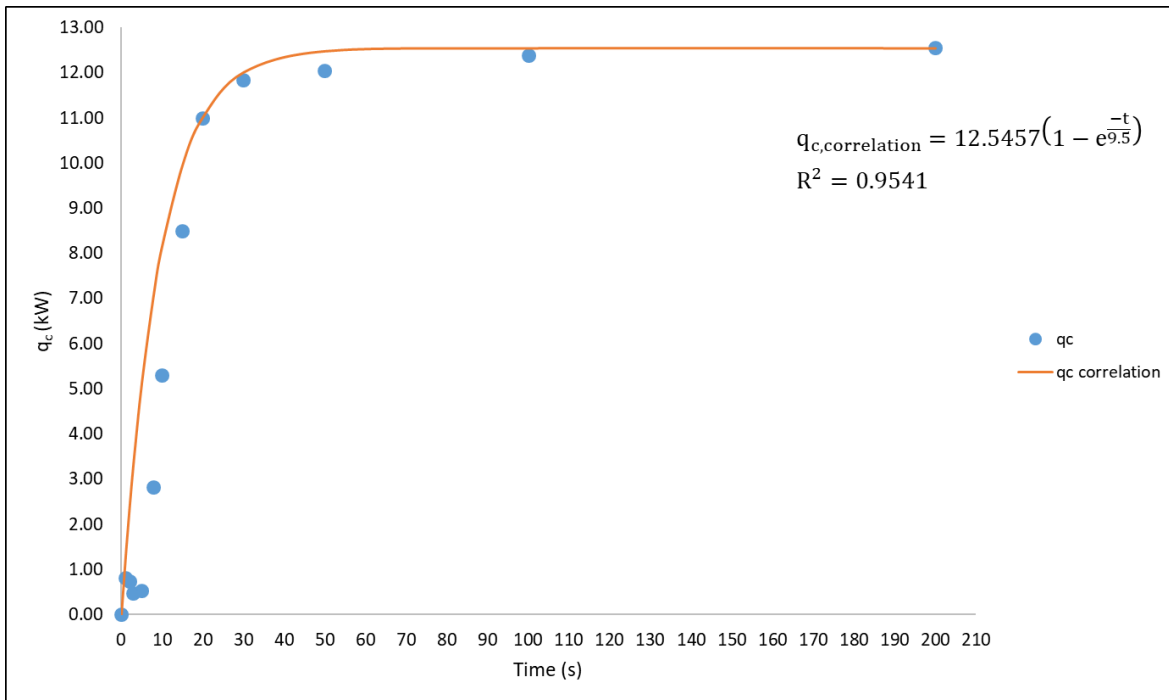


Figure P7: First order time response for R3-60 at 14LPM

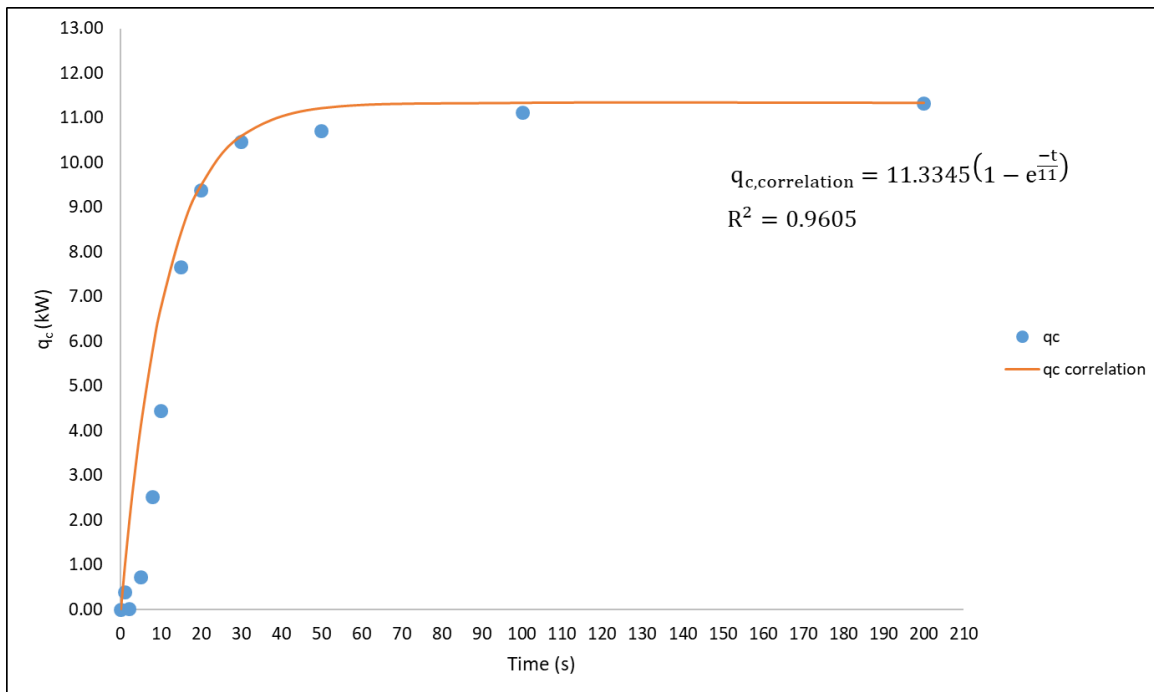


Figure P8: First order time response for R3-60 at 12LPM

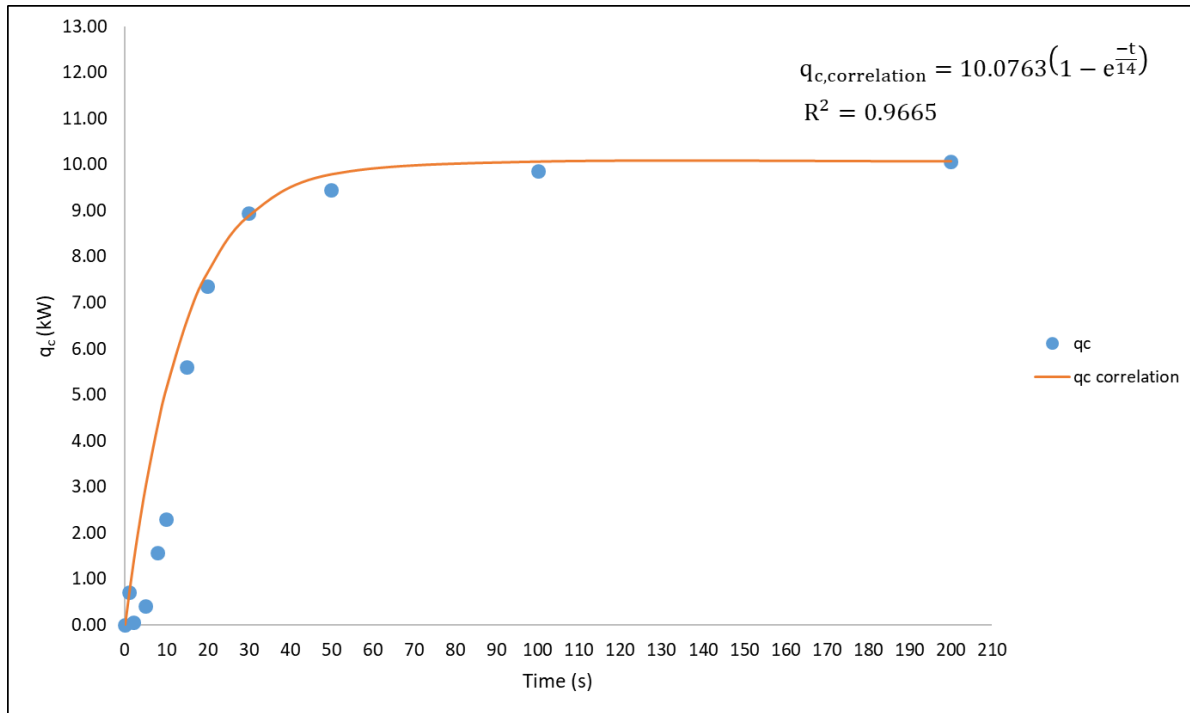


Figure P9: First order time response for R3-60 at 10LPM

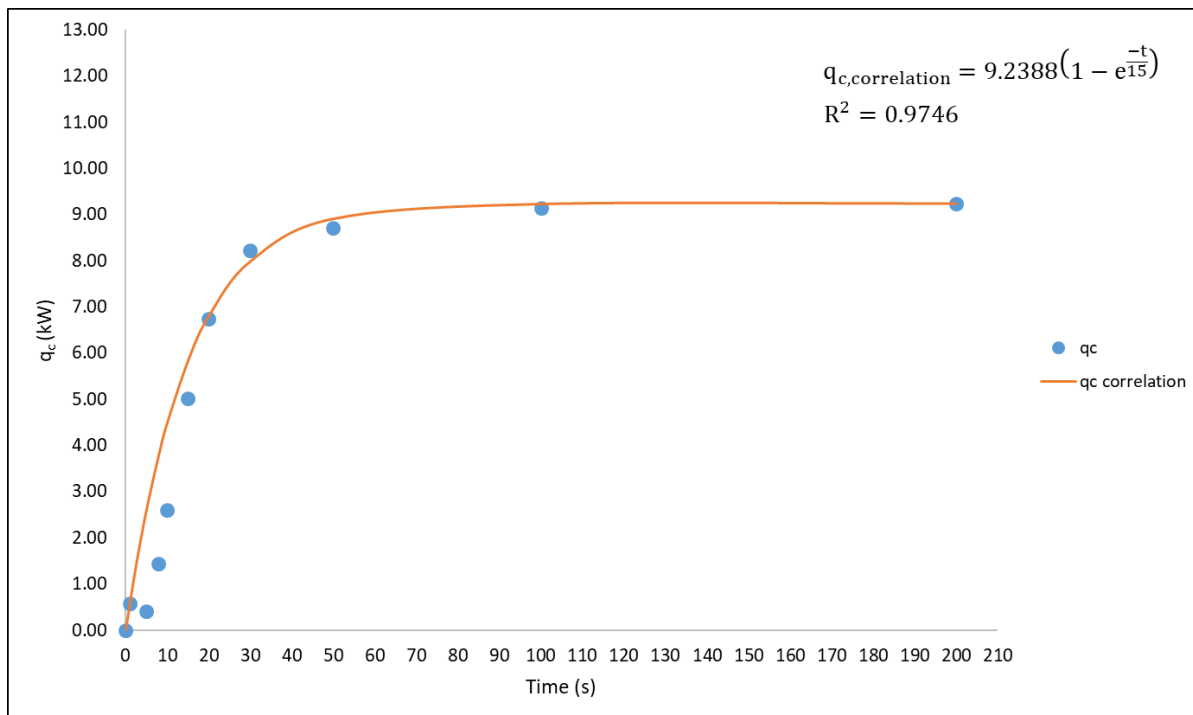


Figure P10: First order time response for R3-60 at 9LPM

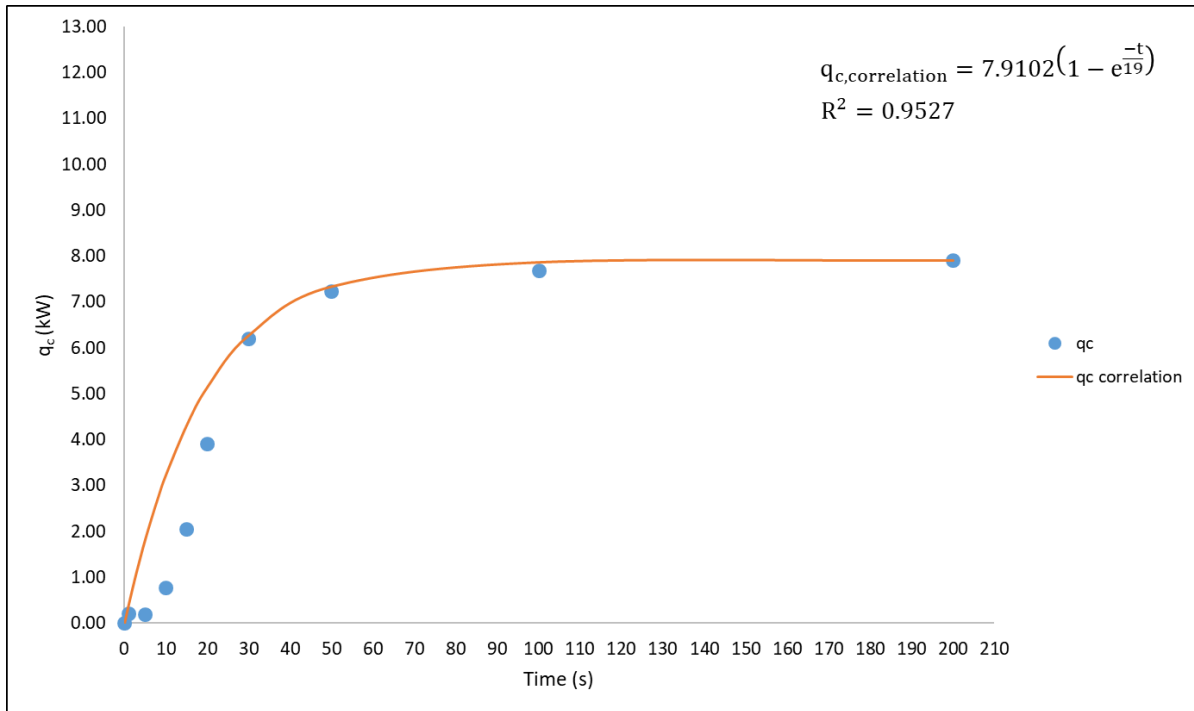


Figure P11: First order time response for R3-60 at 7LPM

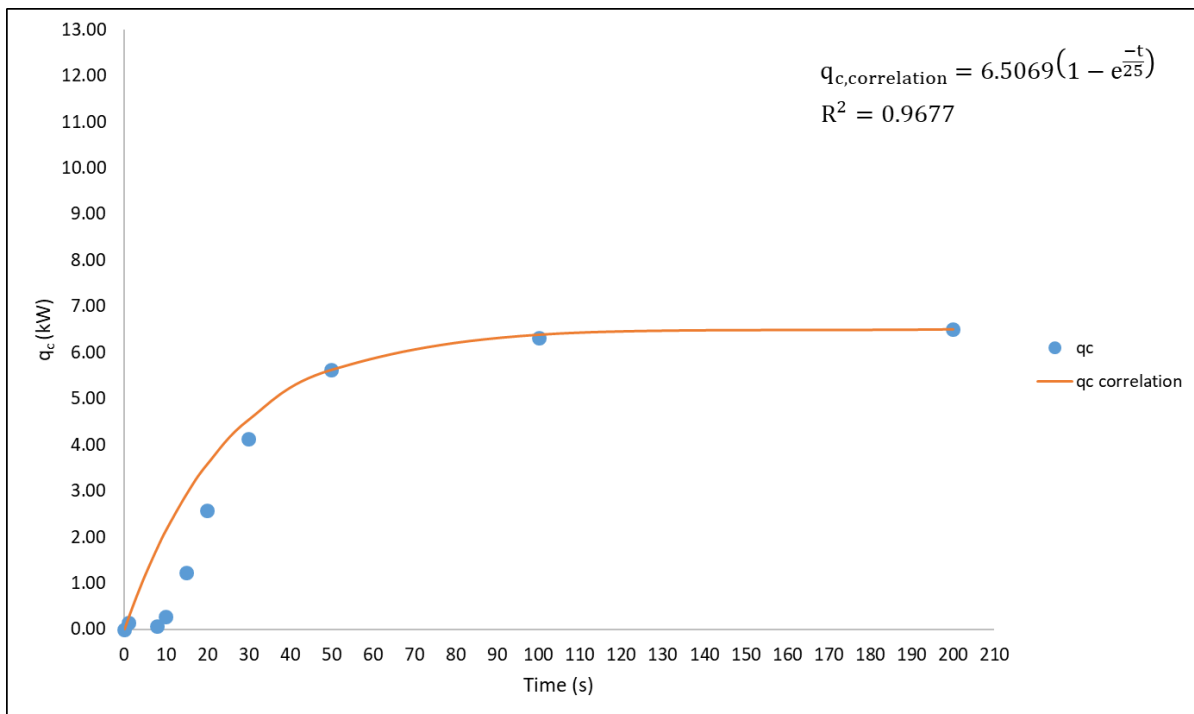


Figure P12: First order time response for R3-60 at 5.5LPM

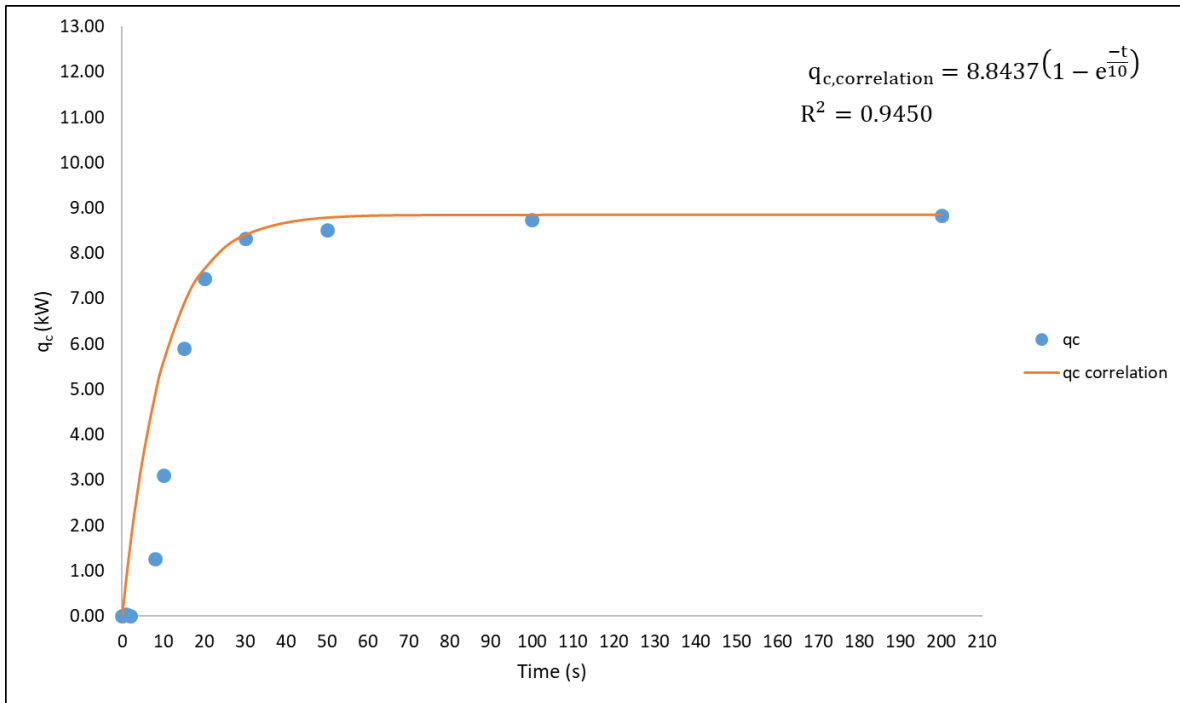


Figure P13: First order time response for R4-36 at 14LPM

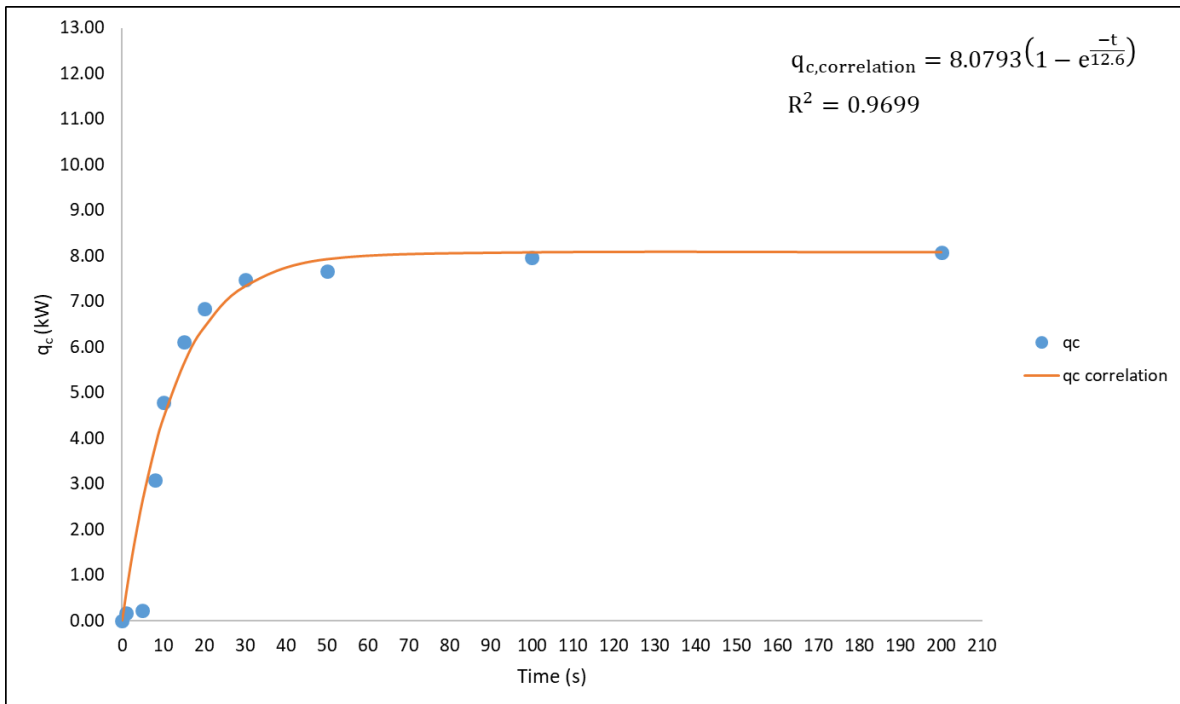


Figure P14: First order time response for R4-36 at 12LPM

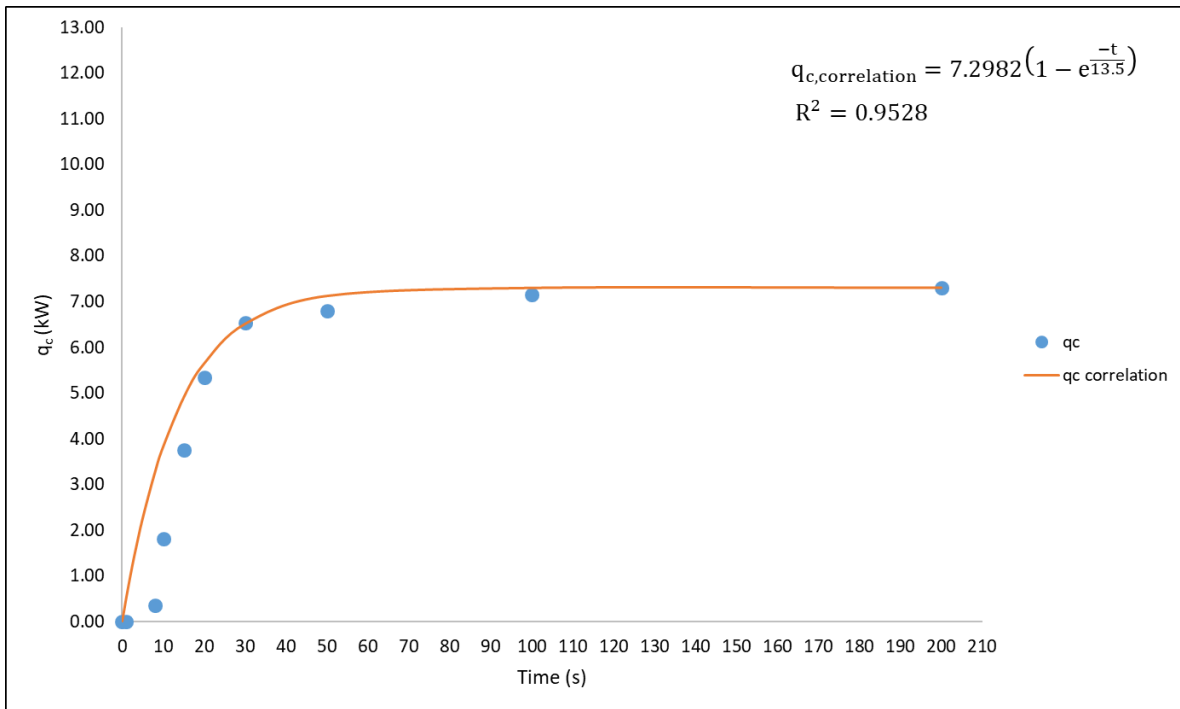


Figure P15: First order time response for R4-36 at 10LPM

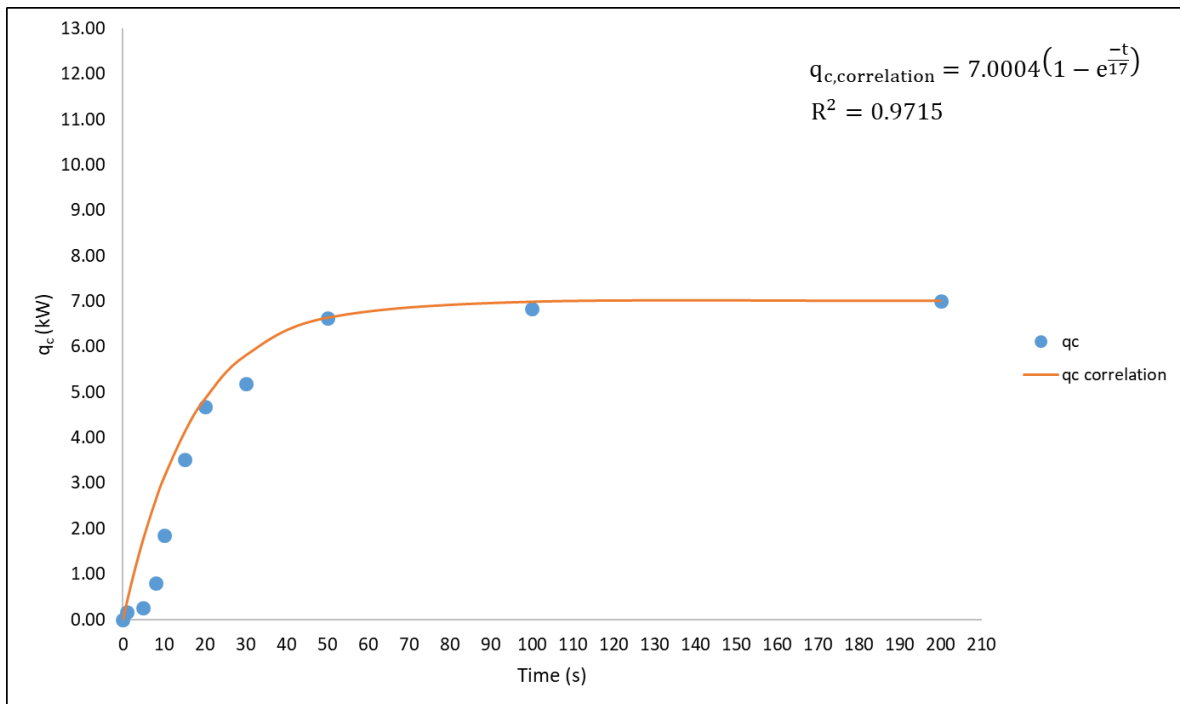


Figure P16: First order time response for R4-36 at 9LPM

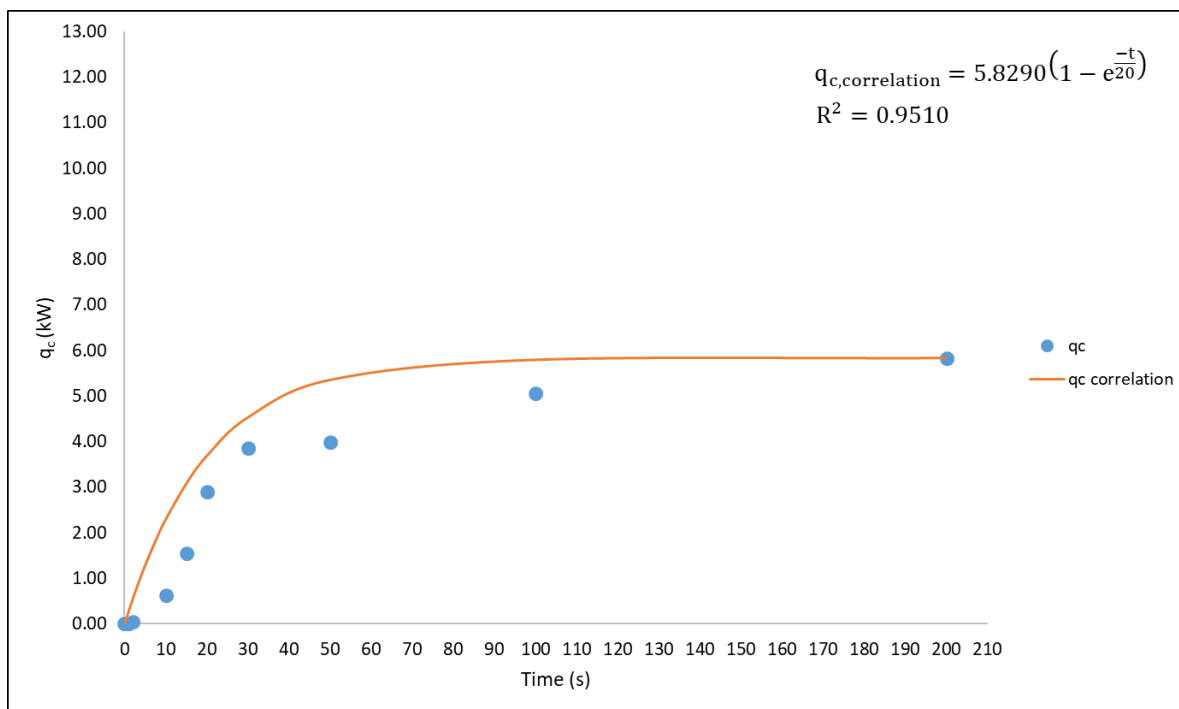


Figure P17: First order time response for R4-36 at 7LPM

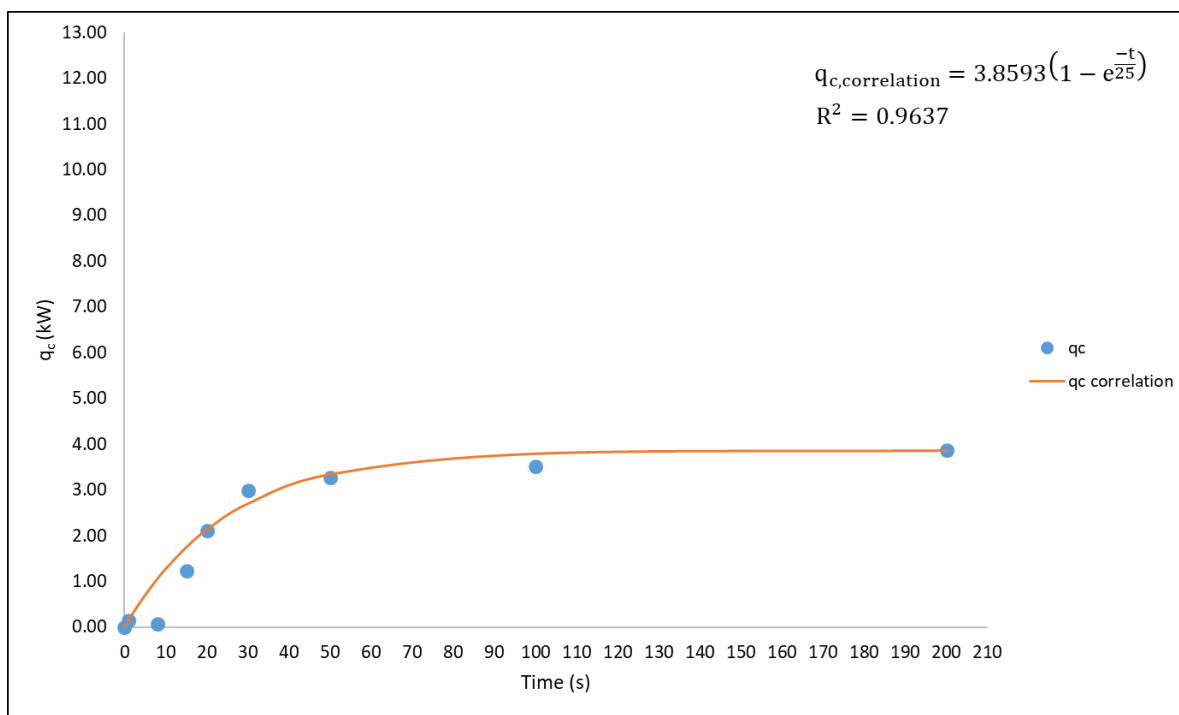


Figure P18: First order time response for R4-36 at 5.5LPM